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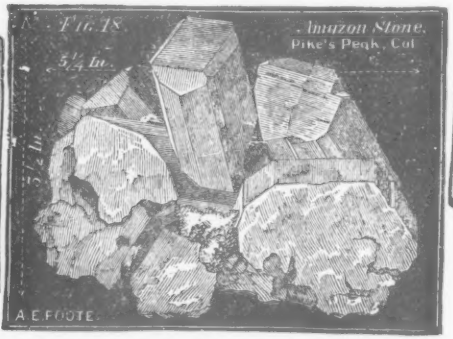

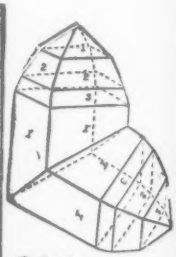

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AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XII.—*On the Use of a Free Pendulum as a Time Standard*;* by T. C. MENDENHALL.

THE use of the new half second pendulums in the gravitation work of the U. S. Coast and Geodetic Survey has suggested the possibility of employing a pendulum with the improved methods for ascertaining its period in terms of a clock or chronometer second, as a standard of time which in constancy and ease of application might go beyond anything now readily attainable.

The natural though not necessarily invariable unit of time is the sidereal day and while it is sufficiently constant to satisfy all requirements it is inconveniently long for nearly all operations, other than astronomical, in which great precision in time measurement is required. Its subdivision is, therefore, rendered necessary and this is accompanied by rather more uncertainty than usually belongs to the subdivision of a standard. Even the daily rate of our best clocks and chronometers is by no means constant and it is safe to say that in most cases little if anything is known regarding their hourly variation from the mean for the day. That such variations, due to fluctuations in temperature, pressure, and other less known causes, exist is well known to all. In the physical, physiological or other laboratory, in which it is desired to determine intervals of time with a high degree of accuracy it is common to depend upon the daily rate of chronometer or clock, which rate is itself determined by means of clock signals from an

* Read at the meeting of the National Academy in New York, November 11th, 1891.

established astronomical observatory, or directly by the use of a transit instrument. In the former, rates are carried during bad weather and often for many days, by one or more clocks and with greater or less accuracy but the signals as received are subject to uncertainty and error arising out of telegraph transmission. In the latter, a few nights in succession of cloudy weather prevent the observer from getting a rate for his time-piece just when he most needs it. In both cases the daily rate is usually all that is known, although this may differ widely from that existing when the particular experiment was made for which the time is to be standardized. It is believed that a free pendulum, vibrating under constant conditions furnishes a much more reliable standard for short intervals than any clock or chronometer and that this standard may be easily utilized by methods about to be described.

The pendulum* is for convenience, a half second's pendulum and is, therefore, about a quarter of a meter long. Its mass is only a trifle greater than a kilogram and the most of this is concentrated in the bob. The knife edge, rigidly attached to the pendulum, is of agate and it swings upon agate planes. These should be rigidly supported and may well be secured to a part of the casting which furnishes at once the support for the pendulum and the chamber in which it swings. It should be furnished with a starting and stopping apparatus and an arc for measuring the amplitude of its vibrations. If it is to be used only for comparing chronometers and clocks no arrangements for securing constant pressure and uniform temperature are necessary. If it is to be a time standard both should be provided. The first is easy and the second can generally be reached quite closely. Some method of knowing the temperature of the pendulum should be provided. When used under conditions of nearly constant temperature a "dummy" pendulum, in the same enclosure, with a thermometer properly embedded in its stem, will be sufficient. Its amplitude should not be greater than two degrees at first, and when the knife edge is properly prepared it will swing for a couple of hours without this being inconveniently reduced.

The period of the pendulum may be ascertained by means of a modified coincidence method, the elements of which were first applied by Herr Von Sternek in his use of short pendulums in gravity determinations.

A small mirror is placed in a vertical plane on the pendulum head, its center being as near as may be in a horizontal

* The pendulums used in the recent gravitation work of the U. S. Coast and Geodetic Survey will be found figured and described in an Appendix to the Report for 1891.

plane passing through the knife edge. A similar mirror is placed parallel to this and as near to it as is possible without interfering with the motion of the pendulum, but it is rigidly attached to the support upon which the pendulum swings. What is called the "flash apparatus" is placed a meter or two meters in front of these mirrors and in a line normal to them. In this an electric spark may be used or the light of a lamp or candle. What is desired is that a flash of light should be produced every second, as determined by a break-circuit chronometer or clock. For use with a lamp Mr. E. G. Fischer has contrived an ingenious shutter operated by an electro-magnet, by means of which an illuminated slit is exposed for an instant in the movement following the break only. An induction coil whose primary circuit is broken by an electro-magnet in the chronometer circuit provides the electric flash. Just over the point where this flash is produced is placed a telescope.

When properly adjusted the flash is reflected from both mirrors, and assuming the pendulum to be at rest, two lines of light are seen as one in the telescope or better, one is made to overlap the other a little. Now suppose the pendulum to be in motion, it will be clear that, as the flash occurs only for an instant each second, whether it will be seen reflected from the moving mirror will depend on the position of that mirror at the instant of its appearance. If it should happen to be in the plane of its original adjustment when the flash occurs the appearance in the telescope will be precisely the same as when the pendulum is at rest. If the period of the pendulum be precisely one-half of that of the clock or chronometer it will return to this position in just one second and the appearance will be continually repeated. If, however, the pendulum be slightly slow or fast of the chronometer, the mirror will not be precisely in this position at the end of one second and the image from its mirror will be a little above or below that of the first mirror. In another second the distance separating them will be still greater and this will go on until the moving image is no longer seen in the field of the telescope. After a time, however (this period is conveniently about five minutes), the pendulum will have gained or lost one oscillation on the beat of the chronometer and a few seconds before the necessary period for this has elapsed the image re-appears in the field and approaches coincidence, to again recede on the other side.

It is only necessary to observe the instant of this coincidence of the two images. Under the conditions mentioned above it is not necessary to observe this closer than the nearest

second and only an inexcusably careless observer would ever be a second in error. After having ascertained the "coincidence interval" and observed the first coincidence, the happening of any one in the future can be quite closely predicted. It is desirable to allow the pendulum to swing through a period equal to ten coincidence intervals and although only the first and last observations may be used it is well to observe two or three at the beginning and end of the period as a check. An idea of the accuracy of the method may be formed by assuming that an error of one second is made in observing the coincidence either at the beginning or end of the swing. It will be seen that the error of the result will be less than one part in two and a half millions. As a sample of the uniformity of results which is sometimes attained under favorable conditions the periods of a pendulum known as A_3 as obtained from a Negus break-circuit sidereal chronometer in three separate sets of vibrations extending through about an hour each, made on the afternoon of October 23, are here given:

1st	·5006279
2d	·5006281
3d	·5006280

If such a pendulum be properly cared for there appears to be no reason why under the same conditions, its oscillation period may not remain sensibly constant for an indefinite period. As an example of constancy during a short period, a little over half a year, but under unfavorable conditions the following results showing the oscillation period of three pendulums as measured in March last and in October. In both cases time is referred to the standard sidereal clock of the U. S. Naval Observatory. Between the first determination and the last, the pendulums traveled about fifteen thousand miles, were several times landed from a vessel in the surf and with difficulty, and were exposed to great changes of temperature and conditions of weather. The remarkable agreement in the case of all justifies the assumption that a sufficient degree of permanency is attainable.

	Mean Periods.	Washington.	
	A–1.	A–2.	A–3.
March, 1891	·5008779	·5007667	·5006702
October, 1891	·5008759	·5007668	·5006696

When one of these pendulums is compared by means of the flash apparatus above described with a good break-circuit chro-

nometer it is found to furnish a most delicate test of the equality of the seconds determined by the toothed wheel which breaks the circuit.

Any inequality in the spacing of the teeth or irregularity in the movement of the wheel, of the existence of which the ordinary chronograph record would show no evidence, is clearly and unmistakably shown, and if on account of bad workmanship such inequalities are considerable the result as viewed in the telescope is ludicrous although a chronograph sheet from such a chronometer might present a very good appearance. It will be readily understood that when the breaks are separated by uniform periods, the moving flash will advance regularly and steadily, movements corresponding to one thousandth of a second in time being easily perceived. When the breaks are irregular, however, the flash moves irregularly, at times standing still for a second or two, and often actually receding. The apparatus may be used therefore as a test of the regularity of breaks with chronometers or clocks.

It is often desirable to compare one chronometer with another or with a clock and to obtain a relative rate. As this rate is variable it is necessary to determine it by reference to as short an interval of time as possible. The ordinary chronograph record does not give satisfactory results unless the comparison extends over a number of hours or a whole day. By means of the apparatus described in less than an hour a daily rate can be determined, correct within about three-hundredths of a second, and a higher degree of accuracy can be secured if it is found desirable.

In this operation it is only necessary to observe coincidences with both chronometers and then again in forty minutes or after a longer period if a better result is wanted. No care need be taken to secure standard conditions of temperature, pressure, etc., as whatever changes may take place affect the coincidence interval of both time-pieces alike.

Indeed it has been found possible to get a fair rate from an observation of a single pair of coincidences, the time consumed being less than five minutes. It is evident that a method is here offered for studying the hourly variations of chronometers and clocks, due to temperature, pressure, or other changes and in making such investigations the time-piece under examination finds its severest critic not in another of its own kind, but in a free pendulum maintained under uniform standard conditions.

As an example of the comparison of two chronometers by this method the following is cited:

Chronometers. Negus.	1589.			1518.		
	h.	m.	s.	h.	m.	s.
1st coincidence	18	17	15	21	07	10
2d coincidence	19	14	21	22	03	48
Ten coincidence interval..		57	06		56	38

No. 1589–No. 1518 = 28 seconds.

From which the rate is found to be one second per day.

If the claims here made for the free pendulum are justified it is likely to find its most useful application as an independent time standard. For this purpose not less than three of these pendulums should be used. They should have slightly different oscillation periods and these must be determined with great care, under standard conditions and referred to the most accurate mean time second available. Indeed for the first standard set it might be worth while to carry on comparisons during day and night for many days, that all errors incident to the determination of time may be eliminated as far as possible. Assuming the physical constancy of these pendulums and the possibility of reproducing with sufficient accuracy the conditions under which they were swung, no further reference to astronomical observations is necessary, if, only the force of gravity does not change. Such a set, or one derived from it may be issued to any point, with a certificate guaranteeing the periods of oscillation as a simple function of the force of gravity. If the latter is known the oscillation period is at once deduced. Whenever it is desired to rate a clock or chronometer it will only be necessary to observe a series of coincidences, using the pendulum and chronometer as described above. The use of three pendulums, whose differences must remain sensibly constant wherever they are, will serve as a check against changes of any kind and once in a few years a redetermination by means of astronomical time may be had as a further security against systematic error. The ease and accuracy with which their oscillation periods can be determined in terms of the second of a clock or chronometer, and the probable constancy of this period during long intervals of time encourages the belief that the issue of properly authenticated time standards is by no means an impossibility and as to the desirability of an early accomplishment of such an end there can certainly be no doubt.

ART. XIII.—*On the Bear River Formation, a Series of Strata hitherto known as the Bear River Laramie;* by CHARLES A. WHITE.

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IN the year 1859 a series of strata, constituting an important section, was discovered by Mr. Henry Engelmann at a locality in southwestern Wyoming, upon the bank, and near the mouth of Sulphur Creek, a tributary of Bear River one of the members of which section contain abundant remains of a peculiar non-marine molluscan fauna. During the fifteen years following that of their discovery, these non-marine strata were generally spoken of as the Bear River estuary beds, but later explorations have revealed their presence at other localities in Wyoming, Idaho and Utah which shows that they are of more than estuarine extent. During that time also no one expressed any doubt of the Tertiary age of these strata because their fossil fauna, although consisting of new species, included only types which were then regarded as characteristic of the Tertiary, and this view was supposed to be supported by their stratigraphical relation to the other members of the same section and their equivalents in that neighborhood.

About the year 1876 the various deposits, which are now properly referred to the Laramie, began to be generally recognized as constituting one great formation, and these non-marine strata of the Bear River valley district came to be generally known as the Bear River Laramie because they were thought to have been contemporaneous with the true Laramie and to hold the same taxonomic position with relation to other formations, although it was well known that their molluscan fauna is very different from that of the Laramie. They were then also subject to the doubt which certain geologists began to express as to whether the Laramie is properly assignable to the Tertiary or Cretaceous; but this doubt was confined to the question of their geological age and did not extend to that of their relation to those marine strata of undisputed Cretaceous age which constitute other members of the same section. This statement finds support in the fact that up to the year 1891* none of the publications of the various geologists who have examined these non-marine Bear River strata contain any clearly expressed doubt that they are all of later origin than any of the marine Cretaceous strata which occur in that part of the continent. That is, it was understood by them that the

* See Bull. U. S. Geol. Surv., No. 82, p. 153.

Bear River strata rest upon, or hold the same relation to, the equivalent of the Fox Hills group of Meek & Hayden's Upper Missouri section that the true Laramie is known to do.

The object of this article, and of the immediately following one by Mr. T. W. Stanton, is to show that *the strata which have hitherto been known as Bear River Laramie are not only not referable to the Laramie formation but that they occupy a lower position*, being overlain by marine Cretaceous strata the equivalents of which are known to underlie the true Laramie. For this reason I shall in this, and in future writings, designate these strata as the Bear River formation, omitting the term Laramie in that connection as being wholly inapplicable.

The following remarks are offered as a brief historical account of the growth and prevalence of opinion concerning this interesting group of strata, which is paleontologically so different from any other known North American formation.

The first published account of these strata was given by Messrs. F. B. Meek and Henry Engelmann jointly in 1860;* and later in the same year Mr. Meek published descriptions of some of the fossils which characterize them.† In these publications both authors unhesitatingly assign the strata in question to the Eocene Tertiary.

No other publication concerning them seems to have appeared until 1869, when Dr. F. V. Hayden inserted a paragraph concerning them in one of his official reports‡ upon another region, in which he expressed the opinion that they are of Tertiary age and proposed to group them together with the coal-bearing strata of the Sulphur Creek section, those near Evanston and those at Coalville, Utah, as constituting one formation to which he gave the name of Bear River group.§

In 1870 Dr. Hayden published a short article containing a minute description, accompanied by figures, of the non-marine strata originally discovered by Mr. Engelmann in which publication he continued to assign them to the Tertiary.‖

In the same volume, and immediately following the article of Dr. Hayden just mentioned, Mr. Meek catalogued and described a number of new species of fossils among which are some that were obtained from the Bear River formation at and near the originally discovered locality. These Mr. Meek assigned to the Tertiary without comment or qualification.

* Proc. Acad. Nat. Sci. Philad., vol. xii, pp. 126–131.

† Proc. Acad. Nat. Sci. Philad., vol. xii, pp. 308–315.

‡ Prelim. Rept. U. S. Geol. Surv. Colorado and New Mexico, p. 91.

§ The Bear River group as proposed by Dr. Hayden embraced strata belonging to three separate formations. I retain the name for only those which pertain to one of them. That is, for those to which the name "Bear River" has been most generally applied.

‖ Proc. Am. Philos. Soc., vol. xi, 1870, pp. 420–425, pl. 12.

In his official report for 1870 Dr. Hayden republished the substance of his article in the Proceedings of the American Philosophical Society just referred to, in which he again assigned the Bear River formation to the Tertiary, stating its position to be at the top of the Sulphur Creek section. This volume of reports also contains a chapter by Mr. Meek* concerning the fossils which were collected by Dr. Hayden during the previous year, in which he assigned to the Tertiary all those species which were obtained from the Bear River formation.

In Dr. Hayden's official report for 1871, Mr. Meek again catalogued the fossils from the Bear River formation under the head of Tertiary;† and in the same year Mr. T. A. Conrad referred this formation to the Lower Eocene upon paleontological grounds.‡

In 1872 Mr. Meek, in company with Dr. H. M. Bannister, visited Bear River valley and specially studied the section which is exposed along Sulphur Creek, near its mouth, and which includes besides a great thickness of marine strata those of non-marine origin which have just been mentioned as having been first discovered by Mr. Engelmann. The results of this study were published by Mr. Meek in 1873,§ in connection with which publication he gave a figure of the section referred to, accompanied by a detailed description of its members. In this publication he continued to catalogue the fossils of the Bear River formation under the head of Tertiary, but in his remarks upon these strata he for the first time expressed some doubt upon this point, and suggested that they might "belong to the Upper Cretaceous." It is evident, however, that he was still of the opinion that their position is at the summit of the section, and therefore above all the undisputed Cretaceous strata which constitute its other members.

The character of his discussions concerning the paleontology of the Bear River formation in this and in previous publications shows that the doubt referred to was not entertained on account of any evidence afforded by the fossils obtained from those strata, all of which he regarded as of Tertiary types, but he seems to have been influenced by the fact that dinosaurian remains had then for the first time been discovered in strata now known to belong to the Laramie which until then had been by all geologists regarded as of Tertiary age, as also had been the Bear River formation.

* Fourth Ann. Rep. U. S. Geol. Surv. Terr., pp. 149–153.
† Fifth Ann. Rep. U. S. Geol. Surv. Terr., p. 376.
‡ This Journal. III, vol. i, pp. 381–383.
§ Sixth Ann. Rep. U. S. Geol. Surv. Terr., pp. 451–454.

Upon the sheet of the general atlas of the U. S. Geological Survey of the 40th parallel which shows the district traversed by Bear River, the Bear River formation is indicated as belonging to the Laramie, and the areas which it was then known to occupy are colored in the same manner as are the true Laramie areas. This atlas was published in 1876, and the geology of the Bear River district is understood to be the joint work of Messrs. Clarence King and S. F. Emmons.

In his final report also Mr. King assigned the Bear River strata in question to the Laramie;* and he correlated those of the originally discovered locality near the mouth of Sulphur Creek with the uppermost beds of the true Laramie at Black Buttes. Mr. Emmons also, in his final report† assigned the same strata to the Laramie.

At this time the belief had become general that the Bear River formation, notwithstanding the material difference of its fossil fauna from that of the great formation which then began to be known by the name of Laramie, was contemporaneous with the latter, and that both hold the same relation to overlying and underlying formations. For these and other reasons the Bear River formation began, as already mentioned, to be known as the Bear River Laramie; that special designation indicating a recognition of the faunal difference between it and the Great Laramie formation.

The final report of Mr. Engelmann was not published until 1876,‡ sixteen years after the publication of his original report, when discussion as to the true geological age of the Laramie formation, including the Bear River strata, had become somewhat prevalent. Apparently influenced by these discussions Mr. Engelmann in this report expressed the belief that the Bear River strata are of Cretaceous age, although in his original report (loc. cit.) the opinion that they are of Tertiary age is plainly stated.

Mr. Meek's final report to Captain Simpson on the fossils of the Bear River formations is contained in the same volume with that of Mr. Engelmann (op. cit.); and in his discussion of them he too was disposed to assign them to the Cretaceous, but he nowhere indicates a doubt that the taxonomic position of the Bear River formation is the same as that of the true Laramie. He also expressed this opinion in his last published writing,§ where also he described and figured several of the characteristic Bear River species.

* U. S. Geol. Surv. 40th Parallel, vol. i, p. 373 and map III.
† U. S. Geol. Surv. 40th Parallel, vol. ii, p. 327.
‡ See Simpson's Report Great Basin of Utah, pp. 247–336.
§ U. S. Geol. Surv. 40th Parallel, vol. iv, p. 163.

In 1876 also Major J. W. Powell, who had personally examined the geology of the district embracing the lower portion of Sulphur Creek and the adjacent portion of Bear River valley accepted the conclusions which Mr. Meek had reached concerning the order of superposition of the members of the Sulphur Creek section, and published a verbatim copy of Meek's description of it.* In this publication Major Powell assigned the Bear River strata to his Point of Rocks Group, which is equivalent to the Laramie, but both of which he assigned to the Cretaceous, placing the Bear River strata at the summit of the Sulphur Creek section, as all the other geologists referred to had done. In the same volume I described several of the characteristic molluscan species of the Bear River formation.†

In certain of my writings which were published in 1877 and 1878 I assigned the strata which I now designate as the Bear River formation, as well as the coal-bearing beds near Evanston, which are also found in Bear River valley, to the great Laramie formation.‡ Both of these assignments, however, having been erroneous a part of the conclusions which were reached in their discussion were necessarily also erroneous.

The results of some extended field observations made by myself in Colorado, Utah and Wyoming were published in 1879.§ In the part of that publication which relates to the geology of Bear River valley I expressed the views which I then held concerning the relation to the Laramie formation of the Bear River strata and of the Evanston coal-bearing beds. These views were similar to those expressed in my publications of the two previous years except that in the later publication I suggested that the Bear River strata are older than the Laramie; but I based this opinion more upon paleontological, than upon stratigraphical ground. I repeated the expression of this opinion in 1883.‖

In 1879 Dr. A. C. Peale published the results of his examination of the geology of a portion of western Wyoming,¶ in which publications he shows that the Bear River formation has a greater geographical extent than was ever before known. He found these strata occupying a belt of country of varying width, lying partly in Wyoming and partly in Idaho, and extending northward from near the place of their original dis-

* Geology of the Uinta Mountains, p. 158.
† Geology of the Uinta Mountains, pp. 118, 122, 123.
‡ Bull. U. S. Geol. Surv. Terr., vol. iii, pp. 697–614. Ib., vol. iv, pp. 707–724.
§ Eleventh Ann. Rep. U. S. Geol. Surv. Terr., pp 161–172.
‖ Third Ann. Rep. U. S. Geol. Surv, p. 430.
¶ Eleventh Ann. Rep. U. S. Geol. Surv. Terr., pp. 511–644; and map accompanying the 12th Ann. Rep. Also Bull. U. S. Geol. Surv. Terr., vol. v, pp. 195–200.

covery to the 43d parallel of north latitude, a distance of about 100 miles. Besides this he reported the existence of a narrower and shorter belt lying parallel with the other, a few miles farther eastward.

Most of the strata throughout the district examined by Dr. Peale have been much displaced by orogenic movements and the structural geology there is therefore often found to be obscure. Doubtless because of this obscurity he failed to see any reason to oppose the then prevalent opinion that the Bear River formation is referable to the Laramie epoch, and reported that formation as overlying a series of strata which he assigned to the Cretaceous, but admitted that he found no paleontological evidence of their Cretaceous age.

In 1877 and 1878 Prof. Orestes St. John examined the geology of a portion of western Wyoming, his district lying immediately north of the one examined by Dr. Peale, but the results of his work were not published until 1882. In this report* he shows that the Bear River strata which, following the then prevalent custom he assigned to the Laramie, occupy considerable areas in the district examined by him, one of them being a northward continuation of the principal belt reported on by Dr. Peale. These areas show a northward continuation of the Bear River formation of about 40 miles more than was shown by the results of Dr. Peale's observations, and they seem to mark the extreme northern limit of the formation.

The structural geology of Prof. St. John's district is even more obscure than that of Dr. Peale's but his report appears to indicate that no marine Cretaceous strata have been deposited in the immediate neighborhood of the Bear River strata which he found there. Furthermore a proper interpretation of the reports which have been made by various geologists upon western Wyoming and adjoining parts of Utah and Idaho indicate that no true Laramie strata exist within the district where those of the Bear River formation occur. This fact seems to have favored the erroneous identification of the Bear River formation with the Laramie.

From 1881 to 1885 inclusive I published several articles in which reference is made to certain of the characteristic fossils of the Bear River formation.† In all of those articles the

* Twelfth Ann. Rep. U. S. Geol. Surv. Terr., Part I, pp. 175–269 and map.

† The following statement of the titles and places of publication of these articles, in addition to similar references in preceding foot notes, is given for the purpose of making bibliographical reference to the subject of this article as complete as practicable.

Tanganyika Shells. Nature, vol. xxv, pp. 101, 102.

On certain conditions attending the geological descend of some North American types of Fresh-water gill-bearing Mollusks. This Journal, vol. xxiii, pp. 382–386.

New Molluscan forms from the Laramie and Green River groups, with discussion

fossils of that formation are so referred to as to convey the idea of its equivalency to the Laramie. From the latter date to the year 1891, as already indicated, no direct reference to the taxonomic position of these strata seems to have been published.

During the preparation of a Review of the North American Cretaceous Formations which was published in 1891, I found it necessary to discuss the Laramie formation in that connection. While reviewing the literature and paleontology of that portion of my subject, in connection with the results of my personal visits to Bear River valley, I became convinced that the Bear River formation is older than the Laramie,* and that it would somewhere be found overlain by Cretaceous strata. This opinion I expressed on page 153 of the work referred to.

In connection with my official duties upon the U. S. Geological Survey during the past season Mr. Stanton accompanied me to Bear River valley where we together reviewed its geology up to the point where my previous investigations had ceased. It being then impracticable for me to continue field work I left him to pursue his investigations alone, and the following article prepared by him is the result. I need only add that I regard as correct his conclusion that the Bear River formation is not equivalent to the Laramie, but that it occupies a position beneath the greater part, if not the whole, of the equivalent of the Colorado formation of the marine Cretaceous series. That is, instead of overlying the equivalent of the Fox Hills group, or No. 5, of Meek & Hayden's Cretaceous section, the Bear River formation underlies the equivalent of the Fort Benton, or No. 2, of that section.

It is known that certain strata exist in southern Utah in which several of the characteristic species of the Bear River formation occur. Their investigation in the near future, and in the light of the newly ascertained facts which have just been stated and referred to, is contemplated; but because of present want of sufficient knowledge of the relation of those strata to other formations in that district they have not been considered in the foregoing remarks.

of some associated forms hitherto known. Proc U. S. National Museum, vol. v, pp. 94–99, plates 3 and 4.

A Review of the Non-marine Fossil Mollusca of North America. Third Ann. Rep. U. S. Geol. Surv., pp. 411–550, plates 1–32.

Contributions to Invertebrate Paleontology, No. 4; Fossils of the Laramie Group. Twelfth Ann. Rep. U. S Geol. Surv. Terr., Part I, pp. 49–103, pl. 20–30.

The genus *Pyrgulifera* Meek and its associates and Congeners. This Journal, vol. xxix, pp. 277–280.

*Bull. U. S. Geol. Survey, No. 82.

ART. XIV.—*The Stratigraphic Position of the Bear River Formation;* by T. W. STANTON.

THE Bear River formation has been defined and the history of opinion concerning its age and position have been given in the preceding article by Dr. C. A. White. During July and August, 1891, nearly all the well known localities where this formation occurs were reëxamined for the purpose of determining if possible its relations to other formations in the same region. The results of this examination are now presented, and as they differ materially from the conclusions reached by a number of geologists who have visited the region it is thought necessary to give somewhat in detail the facts on which they are based.

The areas studied were (1) at Bear River City,* on the Union Pacific railway twelve miles southeast of Evanston, Wyoming; (2) on Bear River seven miles north of Evanston; (3) near the mouth of Twin Creek and on Ham's Fork, both on the Oregon Short Line; (4) the valley of Smith's Fork from Cokeville, Wyo., twenty miles northward. These localities are scattered over a narrow belt in western Wyoming nearly one hundred miles long extending from latitude 41° 10′ to 42° 20′. They will be discussed in the order in which they are named.

The Bear River City Area.—This is the place of the original discovery of these strata, as mentioned in Dr. White's article, and nearly all of the discussions of them and their equivalents have been based on observations and collections of fossils made at this place. There is here a small area of highly inclined, folded and faulted Cretaceous and other strata surrounded and overlapped by nearly horizontal Wasatch Tertiary beds. The structure of these older beds is very complicated and many of the softer beds of shale are not satisfactorily exposed. It is not claimed, therefore, that all the structural details of this area have been worked out, but sufficient has been learned to enable us to assign most of the exposed strata to their proper relative positions in the section.

The accompanying sketch map which shows the observed dips and strikes of some of the harder strata will render the descriptions more intelligible. Immediately east of Hilliard station there is a ridge of hard light-colored sandstone formed by a faulted anticlinal fold which at this point trends nearly north. The dip on the west side of the fold is about 30° west.

* This is the site of one of the temporary terminal towns on the Union Pacific railway, at one stage in its construction. It is long since abandoned and the place is now locally known as Bear Town.

Associated with the sandstones there are shales and one or more thin beds of coal. Following this ridge northward it is soon seen to curve to the west and finally to the southwest so that it is carried to Bear River City where it ends abruptly.

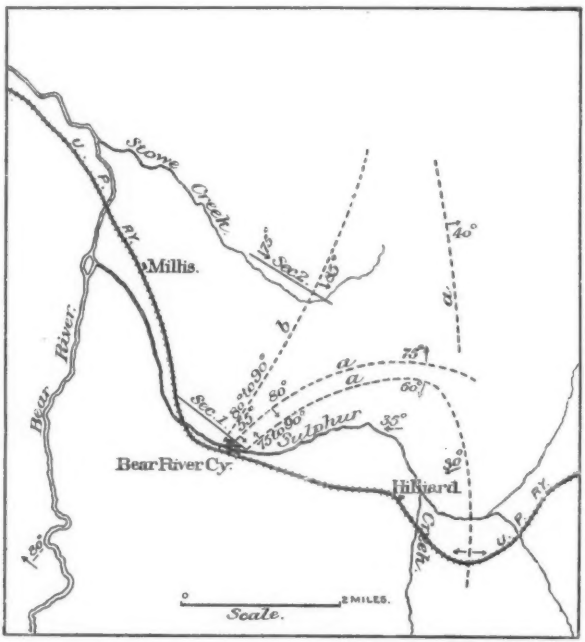


Fig. 1. Sketch map of small area at Bear River City, Wyoming, showing the location of the sections and the approximate dips and strikes of the more important strata.

a, *a*, *a*, ridges of Cretaceous coal-bearing sandstone. *b*, conglomerate ridge west of the Jurassic outcrop. The figures give the amount and the arrows indicate the direction of the observed dips.

The sandstones composing it are there nearly vertical and form the eastern part of Meek's section which will be quoted farther on. The semicircular space thus enclosed is occupied by soft clay shales with a few thin bands of sandstone, all of which show the same curved strike with dips toward the center of the curve. About 250 yards west of the first ridge at Bear River City there is a second less prominent ridge of coal-bearing sandstone that seems also to have a curved strike parallel with the first. It is possible that these two ridges consist of identical strata duplicated by a fault or fold, but positive proof of this was not obtained.

From a point about one and a half miles north of Hilliard another ridge of Cretaceous sandstone dipping 30° to 40° east extends north and northwest for about two miles. The exact relations of this ridge at the intersection with those just described were obscured by surface debris, but it is evidently composed of the same series of beds that constitute the other ridges. The sandstone is underlain by a great thickness 1000 to 1500 feet—of fissile bluish and brownish shales not sufficiently exposed for accurate measurement.

Immediately west of Bear River City there is a prominent ridge the crest of which is formed by a hard brownish conglomerate trending north 28° east. It is nearly vertical and is continuously exposed for about four miles. All the strata immediately associated with this conglomerate and all those west of it have approximately the same strike. These strata are described* in Professor Meek's section on Sulphur Creek, and as my first observations were made on the same section it is reproduced here in order that the new facts may be clearly connected with those already known. In copying the figure (section 1) the first three beds at the east end of the section are omitted, and names of the formations recognized are added beneath.

MEEK'S SECTION.

"No. 1. Black shale, only seen in the bottom of Sulphur Creek, thickness unknown.

No. 2. Slope apparently occupied by clays, thickness perhaps 100 feet or more ..... 100 ft.

No. 3. Soft light grayish sandstone, nearly vertical ..... 90 ft.

No. 4. Covered space, probably occupied by clays, but showing some sandstone that may or may not be in place; perhaps room enough for 250 to 300 feet ..... 300 ft.

No. 5. Two or three rather heavy beds of light yellowish gray sandstone, separated by clays, probably occupying some of the space included in division 4. Near the lower part two layers 15 to 18 inches each, of sandstone, containing *Ostrea soleniscus*, *Trapezium micronema*, etc. Altogether 90 to 100 feet or more ..... 100 ft.

No. 6. Greenish and bluish gray sandy clays, with some dark shale at places ..... 100 ft.

No. 7. Bed of good coal, said to be 7½ feet in thickness .. 7½ ft.

No. 8. Heavy massive bed of light colored sandstone, about 90 feet in thickness, standing nearly vertical, with some 3 to 5 feet of sandy clay between it and the coal of division 7 ..... 95 ft.

No. 9. Gray sandy shales with alternations of sandstone and clay ..... 255 ft.

* Ann. Rept. U. S. Geol. Surv. Terr. for 1872, p. 451.

No. 10. Light gray sandstone ..... 20 ft.

No. 11. Slope and unexposed space, perhaps 200 yards or more across.

No. 12. Light gray sandstones and clays, including a bed of good coal, said to be 7½ feet in thickness; all dipping south-southeast 55° below horizon; and the sandstone above the coal containing many casts, *Inoceramus problematicus*, with a few casts of *Cardium* and undetermined univalves; altogether showing about ..... 150 ft.

No. 13. A valley or depression showing no rocks, perhaps 150 yards across.

No. 14. Ferruginous sandstone in thin layers, dipping northwest about 80° below horizon ..... 40 ft.

No. 15. Bluish laminated clays with, at top (left or west side), a two-foot layer of sandstone, containing fragments of shells not seen in a condition to be determined, 125 ft.

No. 16. Clays and sandstone below (20 feet); gray and brown pebbly sandstone above (25 feet) ..... 45 ft.

No. 17. Brownish and bluish clays, with some beds of white, greenish and brownish sandstones ..... 115 ft.

No. 18. Hard gray conglomerate, standing nearly vertical, and forming crest of hill about 350 feet high ..... 40 ft.

No. 19. Slope showing above some masses of conglomerate, like that of division 18, perhaps not in place, with, at places below this, some reddish clays; altogether space enough for 500 to 600 feet in thickness ..... 600 ft.

No. 20. Greenish-white sandstone ..... 40 ft.

No. 21. Brownish clays and sandy layers ..... 60 ft.

No. 22. Brownish clays and beds of sandstone, the latter light gray below ..... 110 ft.

No. 23. Whitish sandstone—forms crest of hill about 220 to 240 feet in height ..... 40 ft.

No. 24. Conglomerate and some red clays ..... 20 ft.

No. 25. Brownish and reddish clays with a few distantly separated thin beds and layers of gray sandstone, altogether 750 to 800 feet in thickness ..... 800 ft.

No. 26. Gray sandstone in place, apparently connected with some masses (that may not be in place) so as to include space enough for 60 to 80 feet—forms crest of a hill ... 80 ft.

No. 27. A long space of perhaps 260 yards or more, with only a few low exposures of light-gray sandstone, showing a slight westward dip.

No. 28. Numerous thin seams and layers of dark carbonaceous shales, with harder thin bands of various colored argillaceous, arenaceous and calcareous matter, including a few very thin streaks of coal; the whole being highly charged with vast numbers of fresh and brackish-water shells, such as species of *Unio*, *Corbicula*, *Corbula*, *Pyrgulifera*, *Viviparus*, *Melampus*, etc. Dip nearly east, about 75° below the horizon; thickness 175 to 200 feet exposed ..... 200 ft.

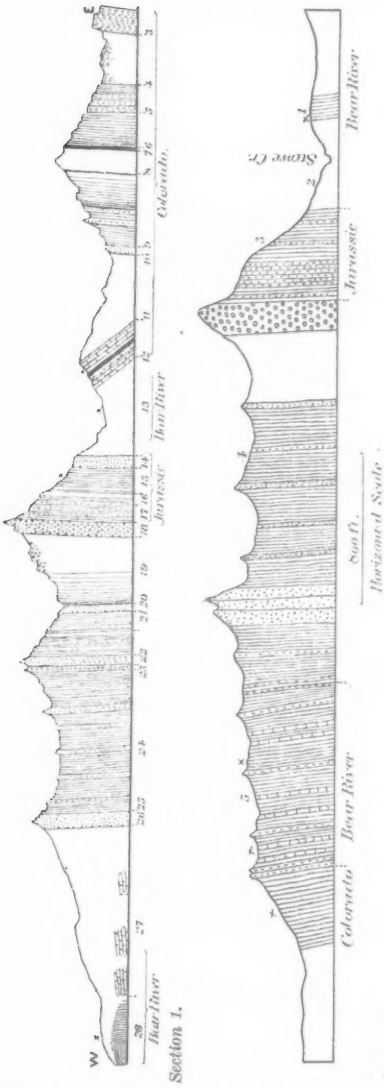


Fig. 2. Sections near Bear River City, Wyo.
Section 1, on Sulphur Creek (after Meek). Section 2, on Stowe Creek. The important fossiliferous horizons are indicated by ×.

It seems to have been assumed by most of the geologists who have visited this locality that the beds above enumerated are in their natural order of sequence beginning with the oldest, and this assumption was in accordance with all the facts then known. They found all the strata in the section, with a few exceptions that have been considered unimportant, practically conformable; that is they are nearly vertical and those at the east end contain well recognized Cretaceous fossils, while those at the west end, composing the Bear River formation, are filled with species that were originally described as Tertiary on account of their modern aspect and their resemblance to certain European Eocene forms. Later the strata were regarded as probably Cretaceous by Professor Meek and others, but their original reference to the Tertiary was tacitly accepted as proof that they must be later than the marine Cretaceous beds in the neighborhood. This circumstance and the uncertainty as to the exact age of the marine Cretaceous strata have had great influence in preventing a correct interpretation of facts observed.

No recognizable fossils had been found in the broad space between No. 12 and No. 28, and the visible structural and topographic features gave no indication of the presence of folds or faults there. On careful search in this space it was found that the fossiliferous layer in No. 15 mentioned by Professor Meek contains characteristic Jurassic species and that No. 13 is in part occupied by fossiliferous Bear River shales, showing that between these two zones there is a fault the existence of which had not before been suspected.

In the space No. 13 several species of Bear River fossils were found on the surface and less than half a mile northeast along the strike the same forms were found in place in calcareous and argillaceous shale of which about 250 feet are exposed. The following forms were obtained:

Pyrgulifera humerosa Meek.
Corbula pyriformis Meek.
Goniobasis chrysalis Meek.
Goniobasis chrysaloidea White.
Goniobasis macilenta White.

These are all characteristic and easily recognizable Bear River forms, all of which occur in No. 28 of Meek's section. The zone was traced by means of small exposures and of fossils on the surface, north-northeast along the strike, to Stowe Creek, a distance of two miles.

500 or 600 feet west of these Bear River strata the fossiliferous layer in No. 15 mentioned by Professor Meek, yielded the following Jurassic species:

Belemnites densus M. and H.
Trigonia quadrangularis Hall and Whitf.
Myacites (*Pleuromya*) *weberensis* Meek ?.

Numerous examples of the first named species were found. It is one of the most common and characteristic forms of the Jurassic of the Rocky Mountain region. *Trigonia quadrangularis* is not so well known, but the type is from Jurassic strata near Como, Wyoming. The *Myacites* is abundant though not well preserved and there is some doubt as to the stratigraphic position of the type specimen which was referred to the Jurassic for paleontologic reasons. The evidence of the Jurassic age of this layer furnished by the first two species is, however, regarded as conclusive. The fossils were found for about half a mile along the strike. The other associated beds that are referred to the same age were so assigned because no reasons were found for separating them.

From No. 14 to No. 27 inclusive only the harder beds are exposed and the descriptions of the others are based on the character of the surface debris. It is evident, however, that none of these strata are duplicated as they would be if the

duplication of the Bear River shales had been caused by a simple fold. This part of the series and the overlying beds are more fully exposed in the section on Stowe Creek, which will be described. The beds in space No. 27 are very much disturbed and only slightly exposed. Besides the nearly horizontal outcrops of sandstone figured by Prof. Meek there are, a short distance east of the fossiliferous No. 28, two almost vertical bands of gray sandstone containing fragments of dicotyledonous leaves, while the outcrops 200 yards north show similar sandstone dipping 45° west. It will be seen on examining the corresponding part of the Stowe Creek section that this confused condition as well as the apparent fold in No. 28 are purely local, the only movement there indicated being a slight change in dip.

On the direct line of Meek's section there are no more exposures for a long distance because it passes into the valley of Sulphur Creek and thence down through the meadows on Bear River. But following the strike of No. 28 less than half a mile north-northeast it was found that the fossiliferous Bear River shales are succeeded westward by thin beds of gray sandstone (about 60 feet) and these by bluish and brownish fissile shales, of which about 1000 feet are exposed, containing numerous teleost fish scales. The strata are then covered for one-fourth of a mile or more to Millis Station where there is a tunnel on a nearly vertical bed of coal six feet thick. The associated beds are not exposed and the hills a short distance northwest are composed of horizontal Wasatch strata.

In the same way the Bear River shales were followed along the strike south-southwest for two miles from the line of the section and were there found to underlie the high hill on the east bank of Bear River. At this most southern exposure there is a covered space of about 500 feet in the meadows along Bear River. The hills on the west bank show some thin bands of sandstone followed by several hundred feet of bluish and brownish shales with teleost fish scales and crushed specimens of a *Prionocyclus* (perhaps *P. Woolgari*). These are evidently the same as the beds above mentioned lying west of the Bear River shales and belong to the lower part of the Colorado formation. A few hundred feet northwest of this locality there is an exposure of 145 feet of alternating sandstones, shales and carbonaceous layers with Colorado Cretaceous fossils. The dip is about 80° northwest, the same as that of the other beds just mentioned. On the uneven edges of this most westerly outcrop of the Cretaceous are the horizontal clays and sandstones of the Wasatch Tertiary. Several years ago Dr. White* gave a list of species collected at this point and referred them to the Fox Hills group. All the identified forms also occur

* 11th Ann. Rept. U. S. Geol. Surv. Terr., p. 248.

in the coal-bearing Cretaceous sandstones near the east end of Meek's section, which are now known to belong to the Colorado formation.*

Two miles north of Sulphur creek another small stream, Stowe creek, has cut a deep valley across the upturned strata showing good exposures of most of them. The following detailed description will show that it supplements the Sulphur creek section, especially in the western half. The strata are all slightly overturned, dipping 75° to 85° east. The beds are numbered from east to west. (See section 2.)

SECTION ON STOWE CREEK.

1. Bear River Formation.	
Obscure exposures of dark shales with calcareous bands containing *Pyrgulifera humerosa*, *Corbula pyriformis*, *Goniobasis chrysalis*, etc.	
2. Covered space about	500 ft.
3. Jurassic?	
Reddish shales and shaly sandstones. Dip 85° east	100 ft.
Light bluish shales with some sandstones near base	120 ft.
Reddish shaly sandstone	200 ft.
Shales and gray sandstones not well exposed	100 ft.
Total	520 ft.
4. Dakota?	
Brown conglomerate of small pebbles. Dip 85° east	150 ft.
Covered in a valley	250 ft.
Brown sandstone	15 ft.
Reddish and bluish soft shales with some thin bands of sandstone mostly covered	350 ft.
Brown sandstone	20 ft.
Variegated shales with thin beds of sandstone	425 ft.
Coarse gray sandstone	200 ft.
Bluish and reddish shales	100 ft.

* The reference of all the coal-bearing Cretaceous sandstones of this neighborhood to the Colorado formation requires a word of explanation. There has been much discussion concerning the age of these beds and their equivalents at Coalville, Utah. A number of invertebrate species have been described from them, none of which excepting *Inoceramus problematicus* was known to occur in any of the members of the Meek and Hayden section east of the mountains. Lithologically they have some resemblance to the Montana (Fox Hills) formation, and they are underlain by beds of dark shales of the Colorado. For these reasons they have been most frequently referred to the Fox Hills, now called the Montana formation. My field work during the last two seasons has shown (1) that a large number of the species of this peculiar fauna occur in the Colorado formation, east of the mountains in southern Colorado, associated with the characteristic species of that formation; (2) that some of these characteristic species also occur in the Coalville beds. We must therefore conclude that the Colorado formation attained an unusual thickness along this western coast of the interior Cretaceous sea and that the local peculiarities of its fauna as well as the greater thickness and coarseness of the sediments are due to the proximity of the shore. These facts will be fully demonstrated in a paper now in preparation and they are mentioned here only because they have an important bearing on the age of the Bear River formation.

Coarse gray sandstone. Dip 85° east	6 ft.
Bluish and reddish shales	75 ft.
Total*	1591 ft.

5. Bear River Formation.

Brown sandstone. Dip 75° east	20 ft.
Soft gray shales	25 ft.
Gray sandstone	10 ft.
Dark shales	60 ft.
Brown sandstone	10 ft.
Dark shales with calcareous bands containing numerous fossils—*Pyrgulifera humerosa, Corbula pyriformis, Unio belliplicatus*, etc.	250 ft.
Sandstone	10 ft.
Dark shales with thin bands of limestone, and sandstone and occasional carbonaceous seams; many Bear River fossils	400 ft.
Gray sandstone. Dip 75° east	10 ft.
Soft shales	25 ft.
Gray sandstone. Dip 75° east	20 ft.
Total	840 ft.

6. Colorado Formation.

Bluish fissile shales with many fish scales and a few marine Cretaceous invertebrates, exposed about	500 ft.

The space for about half a mile west shows only a few small exposures of shales. At this point an opening has been made on a bed of coal six feet thick and dipping 75° east. This is doubtless the same coal bed as that which occurs at Millis station. The associated strata are concealed by soil and by debris from the horizontal Wasatch beds that cap the adjacent hills.

East and north of this section, in the area between the ridges indicated on the foregoing map, there is a valley in which there are no exposures excepting around its margin. On the east side, as has already been mentioned, the Cretaceous sandstones with a strong eastward dip are underlain by 1000 to 1500 feet of shales with fish scales, *Cardium paupereulum*, etc., that are the equivalent of the shales overlying (west of) the principal exposures of Bear River beds. It will be noticed that these shales do not appear in the section on Sulphur Creek between the eastern belt of the Bear River formation and No. 12. The latter which is evidently not in its normal posture, seems to have been thrust over on the shales thus concealing them. A short distance north of the section the divergent strike of the two formations gives ample room for the shales though they are not exposed.

*It is probable that a large part of this member of the section belongs to the Bear River formation.

From the facts just given in detail the following deductions are made:

1. The latest strata embraced in Meek's section on Sulphur Creek are not those of the Bear River formation as he supposed but are the dark shales, No. 1, at the east end of that section which occupy a syncline between Hilliard and Bear River City.

2. Between Nos. 13 and 14 of Meek's section or perhaps within the space No. 13, a reversed strike fault along the axis of a sharp anticlinal fold has brought Jurassic strata in contact with the eastern belt of fossiliferous Bear River shales, concealing the intervening beds.

3. These recognized Jurassic strata are overlain by a considerable thickness of conglomerates, sandstones and shales of which the age is not known, though for stratigraphic reasons they are doubtfully referred to the Dakota.

4. The Bear River formation rests on the last mentioned beds and as just indicated is conformably overlain by the shales and sandstones of the Colorado Cretaceous.

It will be seen that the facts obtained at other localities tend to confirm these conclusions.

The Area seven miles north of Evanston.— From Evanston northward along the east bank of Bear river for five or six miles the hills consist of reddish brown conglomerates, sandstones and shales at the top underlain by lighter colored sandstones with shales and heavy beds of coal (the Almy mines), all dipping 10° to 15° southeast. Dr. White in his later writings refers all of these beds to the Wasatch while Mr. Emmons and others have regarded the coal as belonging to the Laramie. A short distance north northwest of the most northerly of the Almy coal mines is a hill composed of the characteristic shales of the Bear River formation with very many fossils, including almost all the species found in that formation at Bear River City. The beds are exposed for a mile or more northward parallel with the course of the river. They have about the same, or in some places a less dip than the coal-bearing series, with which they have no other characteristic in common. The contact between the two formations is concealed in a valley where there is probably a fault. On the west slope of the hill, adjacent to the river valley, the Bear River shales are unconformably overlain by soft reddish brown sandstones and shales of the Wasatch Tertiary, dipping west, so that both the top and the bottom of the Bear River beds are effectually concealed.

It is worthy of note that about six miles north of this locality a high ridge of Carboniferous limestone is brought up by a fold the axis of which if prolonged would pass a little west of the Bear River exposure. The conditions observable in this area, however, throw comparatively little light upon the question of the taxonomic position of the Bear River formation.

All of the localities remaining to be considered are in the area which was examined by Dr. A. C. Peale in 1877, by whom collections of fossils were made from the Bear River strata at the most of them. His report* on the region referred to was published in 1879 and his map of it accompanied the twelfth annual report of the Survey of the Territories which was not issued until 1882.

Localities on Twin Creek and Ham's Fork.—Thirty-five miles north of Evanston at Sage station, near the mouth of Twin creek, there is an abandoned mine on a thin bed of coal dipping about 35° northwest. Above the coal there is a considerable thickness of sandstones interstratified with argillaceous and siliceous shales none of which yielded any fossils. In a thin bed of sandstone, 15 or 20 feet below the coal *Modiola multilinigera*, *Barbatia coalvillensis* and a few other species of the Colorado Cretaceous were found. 400 or 500 feet east of (below) this there are exposures of sandstones and calcareous shales containing Bear River fossils, interstratified with thin seams of coal on some of which excavations have been made. A figure of the section and a list of the Bear River species collected here has been published† by Dr. Peale. He states that the fossils there enumerated came from above the coal. It is probable however, that one of the lower coal seams is referred to and that the bed in the Colorado formation was not then opened. On the south side of the creek less than half a mile from the coal mine there are obscure outcrops of a fossiliferous Tertiary limestone that also dips northwest, showing that it is involved in the folds and faults of the neighborhood.

On Ham's Fork there is a somewhat similar condition of things. This locality is about twenty-five miles east of the one last described and a mile east of Waterfall station. On the western border of the small area mapped as Jura-Trias by Dr. Peale there is a very small exposure of Bear River beds dipping 45° to 70° west. The fossils obtained include the following characteristic forms;

Pyrgulifera humerosa.
Corbula pyriformis.
Corbicula durkeei.
Unio vetustus.
Unio belliplicatus.

The apparent thickness of the calcareous shales containing these fossils, with the associated thin bands of sandstone, is 30 or 40 feet, and the length of the exposure is only about 200 feet. The contact with the underlying beds is not shown. They consist of reddish brown and purplish shales and beds of hard brown and gray sandstone with variable westward dips.

* 11th Ann. Rept. U. S. Geol. Surv. Terr., pp. 511–646.
† Op. cit., p. 575 and Pl. LXVII.

On the west the Bear River formation is overlapped by a light-colored calcareous sandstone, interbedded with greenish clays and soft yellowish sandstones. The dip varies from 10° to 20° west and the total thickness seen is about 50 feet. The calcareous band contains *Goniobasis tenera*, *Unio haydeni*, *Viviparus paludinæformis* and other characteristic species of the Wasatch Tertiary. The few exposures in the space extending one half mile farther west shows that these Wasatch beds are folded in a gentle syncline beyond which the shales, sandstones and coal seams of the Colorado Cretaceous appear with dips varying from 20° to 29° west. The top of the exposed section is formed by the sandstones of Oyster Ridge, which are, in part at least, the equivalent of similar Cretaceous sandstones at Bear River City and at Coalville. It is believed that a large part of the Bear River formation and a considerable thickness of Colorado shales and sandstones are concealed beneath the folded Wasatch Tertiary beds above mentioned.

The Valley of Smith's Fork.—Smith's Fork empties into Bear River at Cokeville (formerly called Coketon) nearly twenty miles north of Twin Creek. The last three miles of its course is west, but above that for twenty miles it flows almost south. The stream was followed for that distance to the second great bend in its course where it approaches nearest to the head waters of Thomas' Fork. The narrow drainage area of this part of the stream is only from four to eight miles wide and lies between the Sublette range on the west and a nameless range, the southern continuation of the Salt River range, on the east. Nearly all the beds underlying this valley belong to the Bear River formation which has here a greater thickness than at any other locality visited. The strata are much folded, there being an anticlinal fold and two synclinals—one of which is replaced by a fault in the southern portion—between the two ranges and parallel with them.

A few detailed sections are given below to show the structure, and for comparison with the sections near Bear River City.

At Cokeville the Carboniferous limestones are brought up in a sharp broken fold forming prominent hills on both sides of Smith's Fork. The upper portion of the overlying strata that are doubtfully referred to the Triassic yielded a number of imperfectly preserved fossils belonging to the genera *Aviculopecten*, *Lingula*, *Camptonectes* (?) etc, that have not been specifically determined. They indicate that the strata containing them are certainly not later than the Jurassic and they are believed to belong to the "Meekoceras Beds" which have been referred to the Triassic. The beds immediately overlying are concealed by a fault which brings these Triassic (?) limestones in contact with the Bear River formation which rests on a

series of alternating sandstones, shales and conglomerates Beneath the conglomerate there are reddish brown thin bedded sandstones and sandy shales forming the axis of an anticlinal fold. No fossils were found in the latter beds but they have a close resemblance to the strata in which Jurassic fossils were found near Bear River City, and they are separated from the Bear River formation by similar conglomerates and sandstones at both places.

COKEVILLE SECTION.

From the mouth of Smith's Fork eastward.

1. Carboniferous.	
Blue limestone and shales in a sharp anticlinal fold	1200 ft.
Thin bedded limestone and shales with some arenaceous layers	600 ft.
Total	1800 ft.
2. Triassic?	
Red shales and sandstones not well exposed	700 ft.
Blue, limestone with *Aviculopecten*, etc. Dip 70° east,	150 ft.
Total	850 ft.
3. Bear River Formation.	
Covered about	50 ft.
Dark shales with carbonaceous seams and calcareous layers containing numerous specimens of *Corbula pyriformis*, *Unio belliplicatus* and other Bear River species. Dip 60° west. This is seen in a tunnel that has been driven in search of coal.	
Mostly covered for a distance of 2250 feet. In this space there are some small exposures of shale and two or three bands of sandstone one of which contains *Ostrea*.	
Variegated shales and thin bands of sandstone. The west half contains *Pyrgulifera humerosa*, *Goniobasis macilenta*, etc., and several seams of coal on which some mining has been done. Dip 80° west. Thickness about	700 ft.
Total thickness probably	2500 ft.
4. Dakota?	
Alternating beds of coarse gray and brown sandstone, and covered spaces that are probably underlain by shales	1125 ft.
Brown pebbly conglomerate. Dip 80° west	125 ft.
Total	1250 ft.
5. Jurassic?	
Greenish gray shales and shaly sandstones	75 ft.
Reddish brown thin bedded sandstones with some sandy shales. Dip at top 75° west diminishing to 65° at the base. Estimated thickness to the river	400 ft.
Total exposed	475 ft.

The section here crosses Smith's Fork at the bend and the strata are concealed in the level river valley for a quarter of a mile. Then there are exposures of brown conglomerate and sandstone dipping about 50° east that are evidently the equivalents of the lower beds in No. 4. Still farther west along the north side of Pine Creek there are characteristic exposures of the bluish and variegated Bear River shales, beyond which all the strata are covered for a mile or more to the range of hills that here forms the boundary between the Bear River and Green River drainage areas. The beds on the western flank of this range are the gray and blue calcareous shales that Dr. Peale referred to the Jurassic "Pentacrinus Beds."

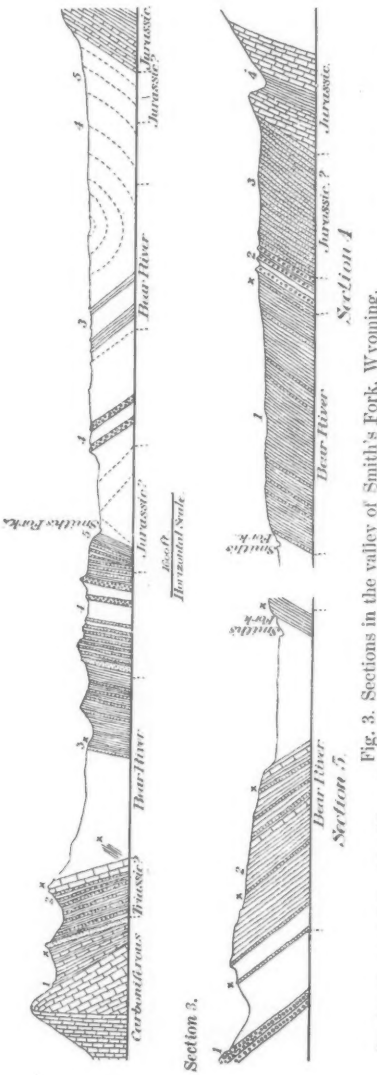


Fig. 3. Sections in the valley of Smith's Fork, Wyoming.
Section 3, near Cokeville, Wyoming. Section 4, east side of Smith's Fork, 12 miles north of Cokeville. Section 5, west side of Smith's Fork, 17 miles north of Cokeville. Fossiliferous horizons are indicated by ×.

The structure indicated by the dotted lines in the figure (Section 3) was seen in the continuation of this belt both north and south of the line of the section.

About twelve miles north of Cokeville a small stream, not named on the maps, cuts a deep gorge through the plateau on the east side of Smith's Fork and shows the general character of the underlying beds. The strike of the strata is generally very constant in this region, nearly parallel with the course of the river. This section therefore

supplements the preceding one as it shows the beds east of the synclinal fold.

Beginning at the river the following beds are exposed in descending order. (See Section 4).

SECTION ON THE EAST SIDE OF SMITH'S FORK.

1. Bear River formation.
   Bluish argillaceous and calcareous shales with occasional thin beds of gray sandstone. Fossils are abundant especially in the upper half. There are also a few fossils (a small Gasteropod and nutlets of *Chara*) at the base. Dip 55° to 60° west. Thickness about ..... 3000 ft.
2. Dakota?
   Brown pebbly conglomerates and coarse sandstones alternating with covered spaces. Total thickness about ..... 500 ft.
3. Jurassic?
   A space nearly a mile wide that is mostly covered but the surface debris and numerous small exposures indicate that it is underlain by reddish brown sandstones and sandy shales. Dip 55° or 60° west. Thickness ..... 3000 ft.
4. Jurassic.
   Greenish gray laminated calcareous sandstone ..... 100 ft.
   Blue and gray calcareous shales. Thickness undetermined.

No. 4 is the "Pentacrinus Beds" of Dr. Peale's general section* of the Jura-Trias in this region.

Five miles farther north a part of the section on the west side of the stream was measured. The river is here in a synclinal valley as it was at the preceding section, but it cuts across the strata at a low angle so that near Cokeville it has passed west of the syncline and cuts through an anticlinal as we have seen. (See Section 5.)

SECTION ON WEST SIDE OF SMITH'S FORK.

1. Dakota?
   Brown conglomerate and coarse sandstone, partly covered. It crops out on the crest and eastern slope of the divide between Smith's Fork and Thomas' Fork. Dip 55° east. Thickness ..... 500 or 600 ft.
2. Bear River formation.
   Covered. Farther north this space was seen to consist principally of shales with obscure Gasteropod casts near the base and with *Unio vestustus* and *Corbicula durkeei* at the top. Thickness ..... 900 ft.

*11th Ann. Rept. U. S. Geol. Surv. Terr., p. 623.

Greenish sandstone weathering to a dark brown. It contains *Unio vestustus*, *Limnea* (*limnophysa*) *nitidula* and a few other fossils. Dip 55° east. Thickness	10 ft.
Covered	300 ft.
Gray sandstone containing a few dicotyledonous leaves* and Gasteropods	10 ft.
Bluish argillaceous and calcareous shales with some thin bands of sandstone. Bear River fossils are numerous in the calcareous layers. The dip seems to remain constant at 55° east to the river plain of Smith's Fork making a thickness of	2200 ft.
Total	3420 ft.

The level meadows of the river plain are about half a mile wide, and the east bank of the stream directly opposite is composed of Bear River strata dipping 60° west.

Three miles north of the last section the divide between Smith's Fork and Thomas' Fork is made up of fossiliferous Bear River shales and sandstones dipping east. The underlying sandstones and conglomerates (base of preceding section) are sharply folded in an anticlinal, west of which the highly fossiliferous Bear River beds again appear in a synclinal. Still farther west along Thomas' Fork the reddish brown thin bedded sandstones and sandy shales beneath the conglomerate are exposed.

General Discussion of the Sections.—The following table based on the detailed sections shows the relative positions of the different Cretaceous formations described and their correlation with the members of the complete upper Cretaceous section of the Northwest, in which the Colorado formation is the equivalent of the Fort Benton and Niobrara groups of the Meek and Hayden section and the Montana is the equivalent of the combined Fort Pierre and Fox Hills of the same section.

TERTIARY.	Wasatch.	Conglomerates, coarse sandstones and shales with coal at the base.
CRETACEOUS.	Laramie.	Wanting, or included in the above.
	Montana.	Not positively identified.
	Colorado.	Shales and coal-bearing sandstones. Thickness not less than 2500 ft.
	Bear River.	Very fossiliferous argillaceous and calcareous shale alternating with thin beds of sandstone.
	Dakota?	Conglomerates and coarse sandstones. Thickness of last two 2500 to 4000 ft.
JURASSIC.	Belemnites Beds.	Thin bedded sandstones and sandy shales.

* The fragmentary plants collected from this formation have not yet been studied.

It has already been shown that the lower 400 or 500 feet of the sections near Bear River City is of Jurassic age. In the more northern areas beds of much greater thickness—not less than 3000 feet—of similar lithologic character and holding the same position relative to the overlying formations are believed to be of the same age, although no fossils were found in them. These beds rest conformably on easily recognizable calcareous shales and limestones from which *Pentacrinus asteriscus* and other characteristic Jurassic fossils have been obtained.

Above these beds comes a considerable thickness of conglomerates, coarse sandstones and shales separated from the preceding by great differences in the character of the sediments, and closely associated with the Bear River formation throughout the entire region, though at a few localities they are not exposed. The conglomerate at the base is a very irregular deposit, varying within short distances from a brown or gray cross-bedded sandstone to a conglomerate composed of pebbles two inches or more in diameter. The general character, however, remains constant and the bed is easily recognized. In the sections I have called this formation the Dakota? ? and have assigned to it in each case all the non-fossiliferous beds above the base of the conglomerate and below the recognized Bear River beds. It is evident that a portion if not all of the strata in these sections between the Jurassic and the Colorado Cretaceous must be the equivalent of the Dakota formation, but the division here made is simply one of convenience.

Of the 3000 to 3500 feet of strata assigned to the Bear River formation at the more northern localities at least 2500 feet contain identified fossils characteristic of the formation. The 900 feet at the base is not usually fossiliferous but it contains nutlets of *Chara* and small Gasteropods indicating that it is of fresh-water origin, and there seems to be no reason for separating it from the overlying beds. The lithologic character of the Bear River formation is very constant throughout the whole region, as the detailed sections have shown. Its thickness increases northward as far as my examination extended. There is not so great a difference in this respect, however, as the arbitrary division of my sections would indicate, for it is probable that near Bear River City enough should be transferred from the Dakota? to the Bear River formation to make the thickness of the latter nearly 2000 ft.

The Colorado formation as it occurs at Bear River City, resting immediately on the Bear River beds, has been sufficiently described. It was not found north of Twin Creek.

The Montana formation was not positively identified at any of the localities studied. Possibly a part of the shales be-

tween Hilliard and Bear River City should be referred to it and it may occur in the upper portion of Oyster Ridge and west of that ridge near Ham's Fork.

The true Laramie does not occur in the region under discussion, unless the coal-bearing series north of Evanston and its equivalent west of Ham's Fork belong to that formation. It has already been stated that the Evanston coal should probably be referred to the Wasatch.

Corroborative Facts.—(1) The reports of Dr. A. C. Peale and Prof. O. H. St. John* show that this formation extends northward beyond Snake River to latitude 43° 45′ and covers considerable areas. Both these geologists state in their reports that they did not find Cretaceous fossils beneath the Laramie, that is, the Bear River formation. At the few localities where they found undoubted marine Cretaceous its stratigraphic relation to the "Laramie" was not determined.

(2) Prof. St. John found it impracticable to separate the post-Jurassic formations of his district, and he frequently speaks of the Laramie, meaning the Bear River strata, as conformable with the Jurassic.

(3) In the Smith's Fork region Dr. Peale mapped a narrow band between the Jurassic and the "Laramie" as Cretaceous, but he did this only because there is a considerable thickness of non-fossiliferous beds (the "Jurassic"? of my sections) overlying the recognized Jurassic and beneath the Bear River formation which was then regarded as Laramie.

(4) The fauna of the Bear River formation is unique. Of the more than thirty species now known in it not one has been found in the true Laramie nor in any of the other fresh-water formations of the West.

These facts were all perplexing as long as the Bear River formation was placed at the top of the Cretaceous, or in the Tertiary, but they become significant and are much more easily explained when it is known that its true position is near the base of the upper Cretaceous and separated from the Laramie by several thousand feet of marine strata.

In conclusion it should be stated that my grateful acknowledgments are due to Dr. C. A. White whose previous investigations had led him to believe that the Bear River formation is older than the Laramie. He accompanied me to the typical localities and identified for me the various points mentioned in previous reports. His suggestions and advice have also aided me greatly in the preparation of this paper.

* 11th Ann. Rept. U. S. Geol. Sur. Terr., pp. 363, etc.; 12th Ann. Rept. Pt. 1, p. 188, etc.; see also sections on plates 4, 7 and 9 and the maps accompanying the latter report.

Art. XV.—*The Iron Ores of the Marquette District of Michigan;* by C. R. Van Hise.

Before considering the subject of this article, it is well to recall the general views held by the late Prof. Irving as to the Lake Superior ore-bearing formations, and those of the writer as to the position and genesis of the ores of the Penokee district. Prof. Irving maintained that the ores, jaspers and associated rocks are derived directly or indirectly by the alteration and silicification of an original lean iron-bearing carbonate.* A detailed study of the Penokee-Gogebic district led the writer to the following conclusions:† First, the original rock of the iron-bearing formation was a lean cherty carbonate of iron, magnesium and calcium; second, the various phases of rock now found in this formation, such as chert, jasper, magnetite-actinolite schists and ore-bodies, are all produced from this original carbonate by various alterations, the processes involved in which are described in detail; third, the ore deposits occur in bodies which all reach the surface of the earth, which have a longitudinal pitch and are roughly triangular in cross-section. One of the lower sides of each triangle is bounded by an impervious dike-rock, the other by an impervious slate-formation; fourth, the ores in their present positions are concentrates produced by downward percolating waters which carried iron carbonate to the apices of the troughs, where it was precipitated by oxygen brought by waters coming more directly from the surface. At the same time silica was removed.

At the close of the description of the Penokee ores, attention was called to the fact that in certain respects the occurrence of the Marquette ores are analogous; but at that time the study of the latter had not extended far enough to give anything more than a general statement that it was probable that the same principles of concentration are applicable to the ore-deposits of both regions. Since that time a systematic investigation of the entire Marquette district has been undertaken, and while the study of the iron-bearing formation is far from complete, certain results have been reached, to set forth which is the object of the present paper.

* Origin of the Ferruginous Schists and Iron Ores of the Lake Superior region, R. D. Irving: this Journal, III, xxxii, pp. 255–272, 1886.

† The Iron Ores of the Penokee-Gogebic Series of Michigan and Wisconsin, C. R. Van Hise: this Journal, III, xxxvii, pp. 32–48, 1889: The Penokee Iron-bearing Series of Michigan and Wisconsin, by R. D. Irving and C. R. Van Hise: Tenth Annual Report of the Director of the U. S. Geological Survey, 1888–89, pp. 341–507.

In much of the field work upon which this article is based, I was in company with Prof. Raphael Pumpelly. The common conclusions reached at this time are consequent upon our joint observations. To Mr. James R. Thompson, Mining Engineer of the Lake Superior mine, I am indebted for detailed observations upon the forms and relations, and for plats of many of the ore-deposits of the Ishpeming-Negaunee area. From these plats several of the figures are taken.

Two ore-bearing formations.—The ore-deposits of the Marquette district occur in two formations. It has been recently recognized that these formations belong to different series, separated by a great unconformity, and therefore that one of the two is much older than the other.* The superior of these is here called the Upper Marquette series, the inferior the Lower Marquette series. The known ore-deposits in the upper series are much less important than those in the lower, and unless expressly stated the Lower Marquette series is always referred to.†

Character of Lower Marquette ore-bearing formation.—The ore-deposits of the Lower Marquette series all occur in or are associated with a single formation, known as the ore-bearing formation.

The non-fragmental character of the quartz and partly individualized silica associated with the ore-bearing formations of the Lake Superior region has been insisted upon in papers already published. The part of the Marquette iron-bearing formation containing the majority of the ore-bodies consists normally of bands of nearly pure silica, alternating with bands composed chiefly of oxides of iron, although frequently bearing more or less silica. The alternating layers are generally not more than an inch in thickness and are more frequently in the neighborhood of half an inch. A single layer, if followed for some distance, is usually found to gradually narrow and die out or to have a rounded oval termination. Sometimes the belts of quartz are so short as to be no more than tolerably long ovals. When the quartz is free from oxide of iron it has a white color and is usually called chert, although the microscope shows that the silica is wholly individualized. When the exteriors of the quartz granules are stained with hematite, or particles of hematite are included within them, giving the siliceous bands a red color, the material is called jasper. It is a general rule that near the top of the forma-

*An Attempt to harmonize some apparently conflicting Views of Lake Superior Stratigraphy, C. R. Van Hise: this Journal, III, xli, pp. 117–137, 1891.

†For the equivalents of the Upper and Lower Marquette series in other parts of the Lake Superior region, see paper cited.

tion the silica is all or nearly all jasperized. In passing to lower horizons less and less of it is jasperized, until in the lower parts of the formation the siliceous bands are white. In the cases in which the jasperization is incomplete, it usually affects the outer parts of the bands and progresses inward. Frequently all stages may be seen between completely jasperized bands and those in which the jasperization has begun to affect only an outer film of the layers. It sometimes happens that above a band of paint-rock or soap-rock the silica is all jasperized, while below it is the white chert. It follows from the foregoing that we have associated with many of the ore-bodies, either banded ore and chert or banded ore and jasper.

The remaining important variety of rock associated with the ore is magnetite-actinolite schist. Where magnetite is the prominent oxide of iron, actinolite or grünerite* is almost always present. In this phase of material the iron is mainly concentrated into layers, giving the rock a banded appearance the same as with the ferruginous cherts and jaspers.

Recent study has shown that iron carbonate is also an important constituent of the ore-bearing formation. Messrs. W. S. Bayley and W. N. Merriam have most frequently found this material at places where the formation dips under a greenstone. In one case iron carbonate occurs abundantly in the deeper workings of a mine. Transitions are seen between the unaltered carbonate and those phases of the formation in which the carbonate is partly or wholly oxidized to limonite, hematite or magnetite.

It is believed that the cherty carbonate of iron, as first advocated by Irving, is the original source of the various forms of ferruginous rocks occurring in the ore-bearing formation. However, it is not the purpose of the present paper to consider in detail the processes by which the many kinds of rocks were produced. This part of the subject for another district has already been somewhat fully treated.†

Associated formations.—In considering the character, position and genesis of the ore-deposits, it is necessary to take into account two associated formations: the overlying conglomerate and quartzite of the Upper Marquette series, and the eruptives.

The eruptives occur in bosses and in dikes. They were originally diabases, but frequently have passed over into diorites, and these again have further altered. In the northeast part of the great ore-producing township of Marquette county, T. 47 N., R. 27 W., is a large area of greenstone. This area

* Notes on Michigan Minerals, A. C. Lane, H. F. Keller and F. F. Sharpless: this Journal, III, xlii, 505–508, 1892.

† Tenth Annual Report, U. S. G. S., pp. 393–408.

is almost encircled by a series of mines, which lie contiguous to the outer border or in the valleys between outlying bluffs. In many cases the greenstone in nearing the ore formation grades into a laminated rock, which has undergone profound alteration as a result of leaching and shearing. Thus changed, it is known as soap-rock, or when stained with iron oxide, as paint-rock. Numerous sections and diamond drill holes have so frequently shown all gradations between the massive diorite and the schistose soapstone and paint rocks as to leave no doubt whatever of their actual continuity. Beside the large masses of greenstone within or associated with the iron-bearing formation are numerous dikes of the same material. These sometimes run nearly parallel to the lamination of the ore-formation, but more frequently cut across it at a greater or lesser angle. These dikes are usually altered throughout, so that in general they have not been recognized as intrusive rocks. Like the altered parts of the greenstone bosses, they are called soap-rock or paint-rock. That they are really igneous is shown by their structural relations, and by the fact that occasionally they are traced to and found to be offshoots from the larger masses of greenstone. These soapstones, as indicated by their name, have a greasy feel, are very soft, have frequently a mottled gray and white color, although often they are deeply stained with red oxide of iron. In chemical and mineral composition these soapstones differ greatly from the original diabases. They have lost nearly all of their alkalies and very often are now largely a hydrated silicate of magnesium and aluminium.

The formation overlying the ore-deposits belongs to the Upper Marquette series and is, as has been said, a quartzite-conglomerate, the material of which is very largely derived from the immediately subjacent formation. The heavily conglomeratic part in some cases is but a few feet in thickness, in others is hundreds of feet thick. The detritus of the quartzite-conglomerate is nearly like the material of the underlying formation, except that within the former no large fragments of pure ore have been observed. This conglomerate suggests that the ore-formation was in approximately its present condition before the deposition of the Upper Marquette series.

General structure of district.—Before dealing with the ore-deposits it is necessary to speak of the general structure of the Marquette district. This can best be appreciated by examining Brooks' geological map.* The Republic tongue is a simple synclinal, the sides of which are nearly vertical, showing that the formation has been sharply folded upon itself. The

* Atlas accompanying the Geology of Michigan, Pl. 3.

southwest end of this trough, where the Republic mine is located, has a pitch to the northwest of 40° or 50°. At the west end of the Marquette district proper the mines, such as the Michigamme, Spurr, Champion, etc., are upon the sides of a great synclinal, which, however, is probably a synclinorium. In the great mining center of T. 47 N., R. 27 W., already referred to, where are the towns of Ishpeming and Negaunee, the formation has been folded into a series of rolls, which have variable pitches, as a consequence of which there are here several iron ranges approximately parallel. The mines, as in the more simply folded part of the district, are frequently at the sides of the synclinals, which, as already said, are generally flanked by diorite ridges. Whether the upwelling of the eruptives was the cause of the folding, or whether as the folding occurred fracture took place in the brittle ore-formation of which the intruding rock took advantage, it is yet too early to discuss.

Classification of Lower Marquette ore-deposits.—The known ore-bodies, with reference to their position, may be divided into the following classes: (1) deposits at the contact of the quartzite-conglomerate and the ore-bearing formation; (2) deposits resting upon soap rock which grades into massive diorite; (3) deposits resting upon dikes of soap-rock which follow along or cut across the ore-bearing formation; (4) deposits interbedded in the jasper or chert. (See fig. 1, p. 123, generalized section of ore-formation in which ore in its more important relations is represented by cross-hatching.)

(*1.*) *Deposits at the contact of the quartzite-conglomerate and the ore-bearing formation.*—The ores occupying this position are generally hard and either specular or magnetic. It is to be remembered that the adjacent rock of the underlying ore-bearing formation is usually banded ore and jasper, although occasionally it is magnetite-actinolite schist. Because of the constant association of the hard ores with the red form of silica this material is sometimes called "specular jasper." One of the largest known deposits of the first class is that at Republic, and this locality, because of its magnificent exposures, is particularly favorable for study. While the main bodies of ore occur at the contact horizon, the mine maps show a constant tendency to form offshoots, a part of the ore following the banding of the jasper formation, which dips at a steeper inclination than the contact plane. (Fig. 2, p. 123). A body may continue in considerable force for some depth, but when it gets far from the contact plane, it is apt to die out. At and below the place where the branch strikes off the main deposit may become somewhat narrower, but in passing downward it often gains its full magnitude, and then a second shoot may start back from the contact plane into the underlying jasper.

Of course the entire contact horizon of the quartzite and ore formation is not occupied by ore-bodies as represented in the generalized figure. The deposits occur at places along the contact where sharp subordinate folding has occurred, or where the jasper formation is broken by cross joints, or where a soapstone dike cuts the contact plane forming a trough; or, finally, by a combination of two or more of these phenomena. The last is well illustrated by the position of the great deposit of the Republic, which is at the southeast corner of the horse-shoe, where the curve, instead of being gentle, is abrupt, causing the jasper formation to become sharply plicated and often fractured (fig. 3), and where there are numerous dikes of soap-rock which usually form one of the boundaries of the ore-deposits. The mining engineer remarked that the ore-deposits cannot live long when they become separated from the soapstone. Upon the east side of the Republic horse-shoe the ore-bodies are in chimney-like forms which often continue for a considerable depth and which are often usually rather sharply separated from the banded ore and jasper adjacent. (Fig. 4). However, here, as at the great deposits, the boundaries are generally found at fractures or flexures.

A detailed examination was made of the manner in which the change occurs between the jasper and the ore. While, as remarked, the ore often terminates somewhat abruptly, it also frequently grades into the jasper. In following a jasper band toward the ore it was found that instead of remaining solid it becomes porous and frequently contains considerable cavities. These spaces in the transition zone are lined with crystalline ore. In passing on toward the ore-deposit more and more of the silica is found to have been removed and the ore has replaced it to a corresponding degree. An examination at many localities led to the conclusion that the transition from the banded ore and jasper to the ore takes place as a consequence of the removal of silica and the substitution of iron oxide. Often in these cases the fine-grained part of the ore is that of the original rock, while the coarser material is the secondary infiltration.

The above details as to the occurrence of the hard ore at Republic are typical of this class in the remainder of the district. In the Ishpeming-Negaunee area, for instance, the ore often terminates along a slip or joint crack. Also the ore-bodies are likely to be found where the folding or crushing of the jasper has been severe, and especially where these phenomena are accompanied by soap-rock.

The ore-bodies between the ore formation and overlying quartzite are not always wholly in the jasper, but often extend upward to a greater or less degree into the quartzite-conglomerate, and some deposits wholly occupy the horizon of the

recomposed rocks. It is reasonable to suppose that a thin stratum of the conglomerate overlying the richer part of the iron-bearing formation may have been nearly, if not quite as heavy in its iron content as the formation from which it was derived. In these cases a part of the iron of the ore-deposit at least is a direct mechanical detritus and differs therefore in its genesis from the remainder of the ores; but all have alike been affected by a secondary concentration, for the process of replacement has affected the siliceous detritus in the same way that it has the laminated jasper in the original formation. When the ore-bodies partly occupy the place of the quartzite-conglomerate and partly that of the ore-formation proper, as a consequence of the secondary concentration, these two formations, although of widely different geological age, have been welded together. This is well shown at the Kloman mine.

(*2.*) *Deposits resting upon soap-rock which grades into massive diorite.*—Here are to be placed many of the deposits of soft ore and some of the hard ores. The masses of soap-rock may follow somewhat closely the lamination of the ore-formation or they may cut across it. In either case the deposit follows along the contact plane, the impervious soap-rock always being below the iron ore and above it the fractured and porous jasper or chert (see fig. 1, p. 123). Not infrequently a mass of soap-rock or diorite forms a synclinal trough in which the ore body rests, when the maximum thickness of the ore is likely to be at the lower part of the synclinal (fig. 5). Sometimes a small dike of soap-rock or paint rock shoots off from the large body and cuts into the ore (fig. 6). At other times the soap-rock bulges into the ore as though it had been bent into sharp corrugations. That the soapstone upon which the ores rest, actually grades into diorite is shown by many drill holes at the Lake Superior mine and very clearly at the Salisbury mine, as well as at other localities.

In some cases the first and second classes of deposits approach close to each other and might be mistaken for one continuous deposit of the same character, the two occupying opposite sides of a synclinal. This is shown by fig. 7, which shows upon one side of the synclinal the following section: diorite grading upward into soapstone, ore, jasper, quartzite-conglomerate. Upon the other side of the synclinal the section is: jasper, ore and quartzite-conglomerate.

(*3.*) *Deposits resting upon dikes of soap-rock which follow along or cut across the ore-bearing formation.*—The ores here belonging, like those of the second class, are usually soft. They may occur upon one side only of a dike rock, or, when it is vertical or nearly so, upon both sides. When two dikes are not far distant from each other the whole or part of the

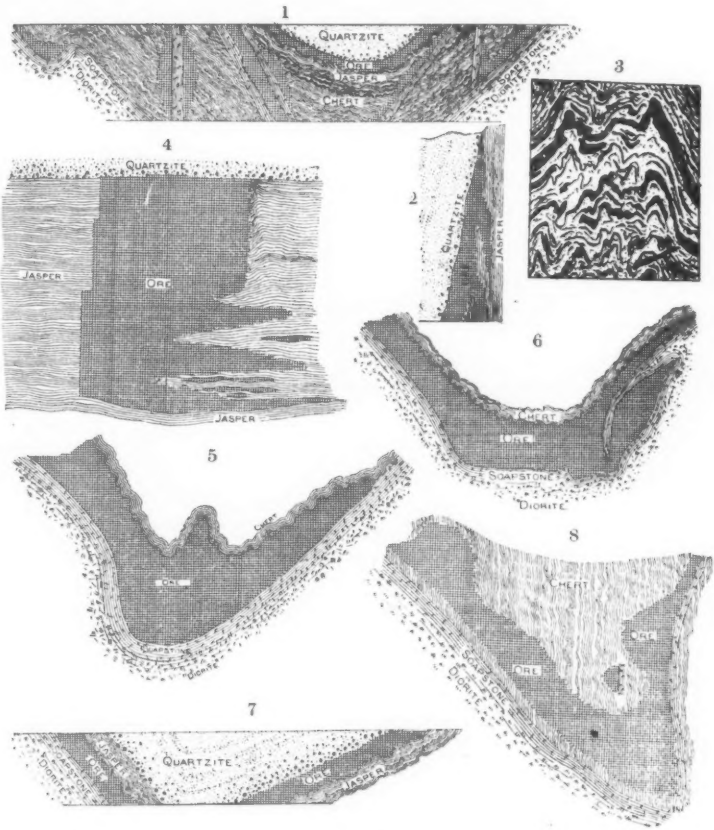


FIG. 1. Generalized section, showing relation of ore-deposits of Lower Marquette series to associated formations.

FIG. 2. Diagram showing tendency of an ore-deposit at contact of Lower and Upper Marquette series, to send offshoots into the jasper parallel to its lamination.

FIG. 3. Sharply plicated jasper (black belts) and ore (white areas), showing shattering of the jasper and concentration of the ore. The ore is proportionally greater where the folding has been the sharpest. Drawn from photograph.

FIG. 4. Horizontal section of ore-deposit on east side of Republic horse-shoe. Left side of ore bounded by a cross-joint; right side is bounded in part by a sharp flexure passing into a joint and in part grades into the lean banded jasper and ore.

FIG. 5. Vertical section of an ore-body, bounded below by soapstone grading into diorite, and above by ferruginous chert; change from ore to chert not so sharp as drawn.

FIG. 6. Another section of the same deposit shown in Fig. 5, but here is seen an offshoot of soapstone from the main mass.

FIG. 7. The ore upon left side rests upon soapstone grading into diorite and is not at the contact plane of the Upper and Lower Marquette; ore at right side is at this contact plane and rests upon jasper. The two combined have a synclinal appearance.

FIG. 8. At the left the ore rests upon the soapstone grading into diorite; at the right it is upon one side of a dike-rock. The dike is an offshoot of the diorite. At the contact of the two a trough is formed in which the ore-body becomes of large size. Figs. 5, 6, 8 from mine plats furnished by Mr. Thompson.

space between may be occupied by ore. When a dike is alone and has a flat dip the ore is always on the upper side, that is in such cases the dike rock is always the foot-wall of the deposit. (See fig. 1.)

A dike carrying ore may unite with a large mass of soapstone varying to diorite, which also carries ore, when a trough will be formed and the deposit is here apt to become large. In this case we have a union of the second and third classes of deposits. At the locality shown in fig. 8 the soap-rock grades into diorite and dips south about 45°, constituting the main foot-wall. Standing vertical and striking 20° or 30° away from the foot-wall is a dike of paint-rock or soap-rock cutting across the formation. Resting upon both are ore-deposits, and by their union at the apex of a trough formed by the junction of the two the ore-body is of large size.

(*4.*) *Deposits interbedded in the jasper or chert.*—No deposits of this class of large size are known, for unless below is a soap-rock (when it would fall into a previous class) no impervious stratum is present upon which the ore can collect, unless (and this does not often occur) a layer of the ore-bearing formation itself locally loses porosity.

The ore-deposits secondary concentrations.—The ore-bodies of the second, third and fourth classes, that is all that lie wholly within the ore-bearing formation, are usually soft, and they may occur at almost any horizon within the iron-bearing formation. Being for the most part at some distance from the contact between the quartzite-conglomerate and ore-formation they are commonly within the ferruginous chert rather than in the banded ore and jasper.

The foregoing descriptions show how intimate is the connection between the ore-bodies and the paint or soap rocks. Mr. Thompson says this connection has become so evident to the miners, and they have such confidence that this material is a favorable indication, that it is called by them "the mother of the ore."

The ore-deposits in longitudinal sections are not horizontal, but generally have a pitch, which in the Ishpeming-Negaunee area is usually to the west and often amounts to as much as 20° or 30°. Consequently the ore-bodies represented in horizontal cross-section are found at different depths in following them longitudinally. This principle of pitch is equally applicable whether the underlying formation is jasper or soap-rock, whether the ore is in sheets, lenses or troughs.

While the ore-deposits of the Lower Marquette series have a greater variety of form and relations than do those of the Penokee district, it is evident that the conditions governing their formation are much the same. In both districts the

material immediately underlying the ore is relatively impervious to water. In the cases of these deposits which rest upon soap-rock this lack of porosity is nearly complete. Many of the ore-bodies are in troughs in the Lower Marquette series, as are nearly all in the Penokee district. The ore-bodies in both in longitudinal section have a pitch. In both the many phases of material found in the ore-bearing formation are nearly the same, and in both is found plentiful residual iron carbonate. It is therefore thought that the explanation of the origin of the ores in the Penokee district is applicable, with few modifications, to those of the Marquette district, although the larger number of the deposits of the latter belong to an older series.

The forms, attitudes and relations of the ore-deposits render it evident that they are not eruptives. No eruptive would be found in such strange shapes and relations. It is equally certain that these irregular masses of ore are not produced directly by sedimentation. All the facts bear toward the conclusion that the ore is a secondary concentration produced by the action of downward percolating water. When the facts are examined in detail, it is seen that the ore-deposits occur at places where circulating waters are sure to be concentrated. The soap-rock accommodates itself to folding without fracture, and while probably allowing more or less water to pass through, acts as a practically impervious stratum along which water is deflected when it once comes in contact with it. It is a common opinion among miners that a few inches of soap-rock is more effective in keeping out water than many feet of the iron-bearing formation. On the other hand, the brittle siliceous ore-bearing formation has been fractured by the folding to which it has been subjected so that where these processes have been extreme water passes through it like a sieve. That the tilted bodies of diorite or soap-rock, especially when in a pitching synclinal or forming a pitching trough by the union of a dike and a mass of diorite, must have guided downward-flowing waters is self-evident. The pitch common to other deposits is also evidence in these cases of laterally deflected downward-moving waters and indicates a wholly or partly impervious substratum even when its character has not yet been ascertained. It is also plain that the contact plane between the quartzite-conglomerate and the ore-bearing formation, that is, the plane of unconformity between the Upper and Lower Marquette series, must have been a great horizon for downward-flowing waters.

If it is true that the whole of the iron-bearing formation was originally a lean cherty carbonate of iron, with perhaps some calcium, and magnesium, or if we go no farther back than the ferruginous cherts and jaspers, it is then concluded

that in order to produce the ore, two things must have occurred: first, the concentration of iron oxide in the places where are found the ore-bodies; and second, the removal of silica from these places.

Time at which concentration occurred.—The final concentration of the Lower Marquette ores occurring at the contact of the Upper and Lower Marquette series must have taken place later than Upper Marquette time. This is indicated by the fact that while these ores are so frequently found at the contact plane the fragments of the overlying conglomerate are almost wholly of the lean chert or jasper, or magnetite-actinolite schist, and include few of the rich hard ore which if present ought to have yielded fragments. This not only shows that the final concentration had not occurred, but that the cherty carbonate (if the assumption be correct that the ore-formation was originally of this material) at the surface had been decomposed before Upper Marquette time. These conglomerates therefore give us an indication of the early character of a part of the ore-bearing formation from which the ore-bodies were later derived. The position of these ore-bodies at the contact plane of the Upper and Lower Marquette series is also evidence that they have been here concentrated subsequent to Upper Marquette time; for it is exceedingly improbable that erosion so generally stopped at a horizon rich in ore, a material which is softer than jasper and would therefore be more rapidly cut out. Further, this contact is not at a certain plane of the ore-bearing formation, but here is at a higher horizon and there at a lower one. Bearing in the same direction, although perhaps not strongly, is the occasional welding of the quartzite-conglomerate and ore-bearing formation already mentioned.

The relations of the ore-bodies within the ore-formation to the diorites and dike-rocks give evidence that the concentration of this ore has occurred subsequently to the intrusion of these rocks. It is certain that some of these eruptives are intrusives later than the Upper Marquette series, since they cut across the overlying quartzite. Others of them appear to have yielded fragments to the Upper Marquette series and therefore antedate these rocks. Finally if the ore bodies had become concentrated before the Upper Marquette folding and erosion, their invariable positions above the impervious formations would be inexplicable. The folding would perhaps have as often left them below as above these formations. Taking all the facts together, it is highly probable that the concentration of all the ores occurred during and later than the folding and erosion subsequent to Upper Marquette time.

Manner of ore-concentration.—Surface waters bearing oxygen passing downward through the Upper Marquette series or

the iron-bearing formation of the Lower Marquette series would decompose the iron carbonates with which they came in contact and thus become carbonated. These carbonated waters would then be capable of taking other iron carbonate into solution. What proportion of the original iron carbonate still remained in the ore-bearing formation at the beginning of concentration is uncertain, but since it is still found in places sheltered from percolating waters, such as the deeper workings of one of the mines and under diorite masses, it is probable that the quantity was very considerable. The oxides or carbonates of iron may also have been taken into solution by organic acids. These downward-moving waters would pass through the iron-bearing formation until they came in contact with an impervious substance or else, if passing through the Upper Marquette series, they reached the contact plane between the two series along which they would travel. It is possible that the ore which formed along the contact horizon was contributed in part by the ferruginous materials of the Upper Marquette series, although it is probable that the greater part of the ore here found came from material of the ore-bearing formation now removed by erosion. After the ore-bearing formation had been leached for a long time, it became as it is now found, very porous along the soap-rock and along the contact plane of the Upper and Lower Marquette series. Here would be carried other oxygen-bearing waters more directly from the surface. The union of these two currents would precipitate the iron oxide. The abundant waters traversing these ore-bearing localities would also slowly dissolve the silica. That this interchange actually does occur is known of the localities in which a detailed examination has been made, as for instance at Republic. It is probable that in the ore-deposits associated with the soap-rocks the removal of silica is due in part to them. Originally diabases, they must have contained alkalies, while analyses of them show at present an almost entire absence of these elements. The alkaline waters produced by their alteration would thus furnish a menstruum capable of taking the silica into solution. This desilicification of the iron-bearing formation by alkaline waters was many years ago suggested by Brooks,* for a part of the Marquette district. Rominger† not only made the same suggestion in reference to the Jackson mine, but further held that the siliceous matter removed, was replaced by oxide of iron carried by water solutions.

The percolating waters which carried material along the readiest paths to form the ore-bodies, and which removed the silica also helped to jasperize the ore bearing formation, i. e. it charged the white silica with oxide of iron and thus reddened it, although it cannot yet be certainly stated to what

* Geol. of Michigan, vol. i, p. 134. † Geol. of Michigan, vol. iv, p. 75.

degree this process had already gone before Upper Marquette time. Whatever the time at which the work was done, the process seems to have been as follows: The upper part of the ore formation was traversed by solutions more extensively than the deeper lying portions. It naturally follows that the ferruginous material was in part deposited about and through the minute particles of silica, reddening them and changing the material from white chert to red jasper. In some places this jasperization has extended deeper than in others and, as already said, it sometimes abruptly stops at an impervious mass of soap-rock. Prof. Pumpelly suggests that before the secondary concentration which formed the ore-bodies, the bands of silica of the ore-formation were white and perhaps in a partly amorphous condition; that at the time of this concentration a partial recrystallization of the silica occurred, affording an opportunity for the ferruginous impregnation so characteristic of the jaspers. A microscopical examination shows that while most of the silica of the entire formation is now individualized, much of the iron oxide of the jaspers is concentrated about the particles of quartz, and that numerous minute flecks also occur within their interiors, thus giving support to Prof. Pumpelly's suggestion.

One or two questions remain to be considered: First, why the ore is so frequently hard and specular along the contact horizon or in the jasper and is usually soft within the ferruginous chert. Second, why the magnetites when present occur at the contact horizon.

An examination of the jasper associated with the hard ores shows that crystallized hematite and magnetite often occur in cavities formed by the removal of the silica. In such geodal cavities these materials have been deposited in a granular crystalline condition. In the continuation of the process the silica was wholly removed and its place taken by the crystalline hematite and magnetite. The adjacent jasper also shows that numerous cracks and fissures have been filled with hematite or magnetite. The manner in which these veins of coarser crystallized material frequently cut across the finer grained substance which represent the iron oxides present before the concentration, shows conclusively that they are secondary infiltrations. The formation of the coarsely crystalline hematite and magnetite thus appears to be connected with the abundance of iron-bearing solutions along the contact plane.

Oftentimes also the hard ores are of the brilliant micaceous or specular variety. In a hand specimen composed of rapidly alternating layers of ore and silica, where the folding has been severe, micaceous ore is often found between the rigid bands of quartz. Along these ferruginous zones is seen all the evidence of slickensides, and the micaceous character of the ore is seen to be due to the shearing to which it has been subjected.

Now the micaceous ore from the large deposits, as first suggested by Prof. Pumpelly, gives the same evidence of shearing. When it is remembered that in the folding of thick formations accommodations and re-adjustments must occur, it is natural to suppose that this re-adjustment has more largely taken place at the contact between the Upper and Lower Marquette series than at any other one horizon, for this is emphatically the plane of weakness. Thus would be explained the finely laminated micaceous variety of ore. It is not impossible that the heat and pressure caused by the shearing along the contact plane would be sufficient to change soft ore into micaceous hematite, but to the writer it appears more probable that these ores represent sheared specular hematite and magnetite. Since the final concentrations of the ores occurred during and subsequent to the folding of the series, it is necessary to believe that this shearing was a contemporaneous process, or else that after it occurred residual silica was replaced by iron oxide and that this metasomatic change did not affect the prior lamination of the original ore. Doubtless both explanations are applicable in varying degrees at different places.

That it is easy to reduce hematite to magnetite is well known, and it is probable that the production of the granular infiltrated variety of this ore is due to the reducing character of some of the solutions which have passed down along the great contact plane of percolation where the magnetites are extensively found. This reducing power could readily be imparted by organic acids. That some kind of reducing agent has been present is indicated by the veins of pyrite which are frequently associated with the magnetic ores.

It is supposed that the magnetite of the magnetite-actinolite schists is due to the direct oxidation of an original carbonate of iron. This is known to be true of the Penokee and Animikie magnetites and also of the magnetite of the Lower Marquette series in the deeper workings of one of the mines. When iron carbonate is decomposed in the presence of an excess of oxygen the sesquioxide is of course formed; but if it is supposed that an insufficient amount of oxygen was present, as is quite probable, from three molecules of iron carbonate would be produced one molecule of magnetite and three of carbon dioxide, if only a single atom of oxygen was available.

Ores of the Upper Marquette series.—The ore-deposits of the Upper Marquette series, so far as studied, show that the original material was an iron carbonate and that the ores are secondary concentrates resting upon impervious formations. Sometimes this impervious formation is a black slate; at other times it is an intrusive basic eruptive; and at still others it is a surface volcanic. As a consequence of folding, or by the junction of two of these basal formations, and of concentra-

tions, the ores occupy troughs or the sides of synclinals. That the ore is a concentrate from an original impure iron-bearing carbonate is easily shown. Wholly unaltered carbonate, often accompanied by organic matter, is abundant, and all stages of the change into the soft hematites and limonites of the Upper Marquette series are seen.

Ores of other districts.—In the Menominee district the ores, as in the Marquette district, occur in two formations, one of which belongs to the Lower Menominee, correlated with the Lower Marquette series, while the other belongs to the Upper Menominee, correlated with the Upper Marquette series. The Upper Menominee is more important as an ore-producer than the Upper Marquette. A detailed study has been made of only a small number of the mines, but a general study has covered nearly the entire district. So far as work has gone, while there will be some modifications of detail, the principles have been found thus far to hold that the ores are secondary concentrations upon impervious formations, and are particularly likely to be of large size when these are folded or two combine to form pitching troughs. Also, as in the Marquette district, the basement impervious formations are often igneous and not infrequently are surface volcanics. At other times, and especially in the Upper Menominee series, the impervious stratum is a detrital slate. As typical instances of the Menominee mines may be mentioned the following: At the Armenia the ore-body is at the bottom and upon the sides of a synclinal trough, pitching at an angle of about 45°. Below the ore is an impervious black slate. At the Mansfield mine the ore-body nearly vertical laterally but pitching longitudinally, has impervious slates upon each side, one of which is clearly a volcanic rock. The ore of the Hemlock mine rests upon an impervious stratum consisting of surface volcanic material.

The ores of the Vermilion Lake district have been studied by us only in a general way, but so far as our investigation has gone all the facts bear toward the conclusion that the principles here hold which are applicable to the other iron-bearing districts of the Lake Superior region. It is true that Prof. N. H. Winchell and H. V. Winchell* have proposed a chemical theory for the origin of the rocks of the iron-bearing formation which does not derive it from a lean iron-bearing carbonate; but even if this theory be accepted (and I do not hold it), it is applicable to the ore-bearing formation rather than to the ore-deposits. The descriptions and figures of the mines published by the late Prof. Alex. Winchell and by Prof. N. H. Winchell, seem to me to be wholly in harmony with our own observations, and to indicate that the Vermilion Lake ores are sec-

* The Iron Ores of Minnesota, N. H. and H. V. Winchell: Bulletin No. 6, Geol. and Nat. Hist. Survey of Minn., Appendix A, pp. 391–399.

ondary concentrates which usually rest upon impervious formations.*

As instances among the mines figured by these authors may be mentioned the following: The ore of the Ely mine is found between impervious schists, the layers of which are inclined. At the Stone mine the ore in its upper workings is in two bodies, each of which rests upon green schists. In its deeper workings these are found to come together and make a solid mass of ore. The ore grades above into the jasper, which is like a great horse separating the upper parts of the deposit. In short, the relations so far as principles are concerned, are much the same as shown in figure 8, taken from a deposit in the Marquette district. At the Chandler mine the ore has its greatest length along and rests upon as a foot-wall, a great mass of greenstone. The upper boundary of the ore is irregular and grades into mixed ore and jasper. It is said of the Ely that the "ore is quite open to the action of percolating water," and that the material shows the effects of crushing and folding. The schists associated with the ores in the Vermilion district are regarded by the Professors Winchell as well as by us as of igneous origin.†

The facts given by these writers then seem to show that the ore is a secondary concentration, instead of that the "ore and jasper" are "of similar and contemporaneous origin." Indeed in the report upon the Vermilion ores, published soon after returning from the field, Prof. N. H. Winchell held, although this position was later abandoned, that the iron ores are later than the siliceous jasper and probably produced by metasomatic change.

It is fully recognized that the explanation above given for the ores of the Lake Superior districts in which mining is now being done, is not wholly if at all applicable to the titaniferous magnetites of northeastern Minnesota associated with the great gabbro flows near the base of the Keweenaw series. In the interstices of these magnetic ores are olivine, augite, feldspar, and often secondary quartz, the whole having a completely crystalline interlocking structure; in other words, they are no more than a very magnetic gabbro. Since these ores occur as basal horizons of the great gabbro flows, it has always seemed to me that this class of deposit is of direct igneous origin. In the crystallization of basic rocks, magnetite is one of the early minerals to separate, and in the immense masses of gabbro, before the magma has solidified the crystals of magnetite have slowly settled by virtue of their superior specific gravity to the

* Fifteenth Ann. Rept. Geol. and Nat. Hist. Survey of Minn. for the year 1886, pp. 24, 25, 221, 235, 255. Bulletin No. 6, Geol. and Nat. Hist. Survey of Minn., pp. 63–67.

† Fifteenth Ann. Rep. Minn., pp. 231, 245, 246; Minn. Survey Bull. vi, pp. 64, 394, 398, 399.

base of the flow, forming thick layers of magnetite. The residual magma has crystallized as the interstitial minerals, and thus we have the titaniferous magnetites of the gabbros. A recent petrographical study by Dr. W. S. Bayley has shown that a part of the magnetite is secondary. As these ores are associated with abundant secondary quartz it is not impossible that much of the magnetite has been brought to its present position after the solidification of the rock.

General.—It is evident that the ores of the Upper Marquette series, like those of the Lower, were concentrated during and subsequent to the folding and erosion which affected both. Thus while the ore bearing formation of the Lower Marquette series is far older than that of the Upper Marquette, and had undergone great changes before the latter was deposited, the local concentration of the iron into workable deposits occurred simultaneously as a consequence of the same great causes. This statement also applies, so far as present knowledge goes, to the two iron-bearing series of the Menominee district. The Penokee series is equivalent to the Upper Marquette and Upper Menominee. The equivalency of the Animikie and the Penokee series and their simultaneous tilting into monoclines on opposite sides of the Lake Superior synclinal has been shown in another place.* It is also shown that this tilting, and consequently the concentration of the ores, occurred subsequently to Keweenawan time. It was suggested that the basic intrusives of the Penokee series upon which the ore-deposits rest are of Keweenawan age. Is it not probable that many of the basic intrusives of like character in the Marquette and Menominee districts are products of the same period?

It appears then probable that the local concentration of the iron ores into workable bodies did not generally begin before Upper Huronian time, while in certain districts it did not begin until much later. That the process has yet ended we have no evidence. The ores of the Lake Superior region occurring in two geological series are remarkably alike. This likeness is plainly due to their similar genesis.

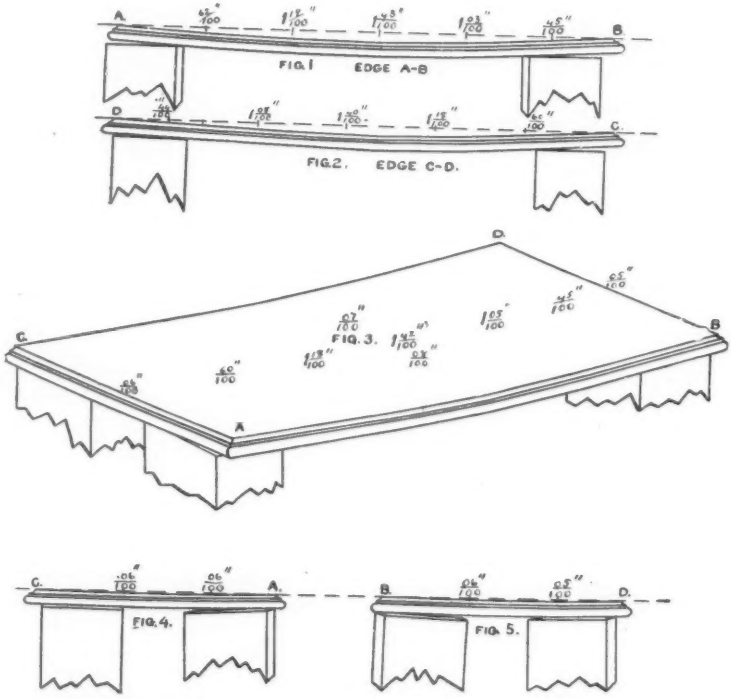
This paper must be considered as an account of the progress of an investigation rather than a complete exposition. While it is possible that a further study will make necessary a modification of certain minor points, it is believed that the principle of secondary concentration along great channels of downward percolating waters, and particularly at places where these waters are converged by tilted impervious formations is nearly if not quite of universal applicability to the workable ore-deposits of the Lake Superior region.

United States Geological Survey.
Lake Superior Division, Madison, Wis., December, 1891.

*Tenth Ann. Rept. U. S. Geol. Survey for 1888–89, pp. 402–408, 458–460.

ART. XVI.—*An Illustration of the Flexibility of Limestone;* by ARTHUR WINSLOW.

THE adjoining cut illustrates an interesting case of the flexing of a limestone slab under moderate stress, applied for a long time. The slab is of white, crystalline limestone or inferior marble and is one of a number in the State lot of the cemetery of Jefferson City, Missouri. Others are seen there



Sketch showing deflection of a limestone slab, due to its weight. Scale 1 inch = 2 feet. Stone erected to memory of Tyrrel P. Bruton, Cemetery, Jefferson City, Mo.

NOTES.—The dimensions of the slab are 6 ft. × 3 ft. × 2 in. It was put in place in the year 1866. The measurements were made August, 1890. The deflections are expressed in inches.

in the same conditions, though the flexing in these has not proceeded so far. It is probable that, in the one illustrated, the extreme condition, without fracture, has already been reached,

if it is not passed, as hair-like lines of incipient fracture are already observable on the lower side of the slab, near its center, running transversely to the length. The slab in question has been in place about 25 years, and the supporting corner posts have settled in such a way that the bearing of the slab upon them is generally only along one edge or along a part of one edge. The carefully made drawing from which the cut is prepared shows all details so well that further description will be unnecessary.

The measurements for this drawing were made by the writer assisted by Mr. A. E. Woodward,* late assistant geologist of the Missouri Geological Survey, and the drawing was prepared by the latter. The deflections were determined by stretching a fine wire tightly across the block from edge to edge, and then measuring the space between the wire and the slab at any desired point with the aid of a pair of dividers. The length of the slab, it will be noticed, is 6 ft., the breadth 3 ft., and the thickness 2 inches. The distance lengthwise, between supports, is about 4 ft., and crosswise between 1 and 2 ft. The sag at the center of the slab, along the lines A–B and C–D, is nearly $1\frac{1}{2}$ inches, beneath the two ends, or about $\frac{1}{50}$ of the total length, or about $\frac{1}{35}$ of the distance between the supports. Assuming the curve to be the arc of a circle, the radius of the circle would be about 37 ft.; or, in other words, a long slab of such marble 2 inches thick, could, under continued stress for a period of twenty-five years, be bent to the form of a circle less than 80 ft. in diameter.

A more detailed study of the measurements yields other facts of interest. Thus an extreme sensitiveness to stress is indicated by the transverse flexing between points of support close together; this is shown by the sections along the lines A–C and B–D. Further, it will be noticed that, along the sections A–B and C–D, the measurements indicate convex undulation between the center of the slab and the points B and D, due to a recurving downwards of the end of the slab, which projects beyond the point of support. At the other end, however, the support is nearer the end of the slab, and here the curvature is continuously concave.

*Died September, 1891.

ART. XVII.—*The Separation of Iron, Manganese and Calcium by the Acetate and Bromine Methods;* by R. B. RIGGS.

HAVING in hand the analysis of a series of samples containing iron, manganese and calcium in large amounts, it seemed advisable to test the two analytical methods involved, namely, the separation of iron from manganese by precipitating it as a basic acetate, and the separation of manganese from calcium by means of bromine. The object was not so much to test the accuracy of the acetate process as to determine the conditions favorable or otherwise to its successful use. In the case of the manganese-calcium separation on the contrary, the value of the method was in question, for where either or both constituents are present in quantities its accuracy has been doubted.

For convenience and accuracy standardized solutions of the three substances were used. Piano wire was the basis of the ferric chloride solution. This was dissolved in hydrochloric and oxidized by means of nitric acid. The nitric acid was in turn expelled by repeated evaporations with hydrochloric acid. Last traces of ferrous iron were oxidized by bromine. The value of this solution was found by means of a standard* permangate solution.

	Weight of $FeCl_3$ solution taken. grm.	Weight of Fe found. grm.	Weight of Fe in 100 grams of solution. grm.	Mean.
(1.)	20·32	0·14957	0·7378	
(2.)	20·335	0·15017	0·7385	0·7382
(3.)	20·30	0·14957	0·7383	

For the manganese chloride solution, manganese dioxide was the starting point. This was digested with nitric acid, dissolved in hydrochloric and nitric acid—twice evaporated to dryness and filtered—treated three times by the basic acetate process (each time allowing a considerable precipitation of manganese), and recovered from solution each time by a bromine precipitation. The last precipitate was dissolved in hydrochloric acid and the excess of acid expelled by evaporation. This solution was standardized by determining the manganese as pyrophosphate.

	Weight of $MnCl_2$ solution taken grm.	Weight of $Mn_2P_2O_7$ found. grm.	Weight of MnO in 100 grams of solution. grm.	Mean.
(4.)	9·98	0·1346	0·6743	0·6739
(5.)	10·095	0·1360	0·6735	

*The permanganate solution was standardized with the same wire so that the results are relatively correct.

The solution of calcium chloride was prepared from calcium carbonate purified by repeated precipitations, as carbonate, by means of ammonium carbonate. It was free from iron, alumina and alkalies.

	Weight of $CaCl_2$ solution taken. grm.	Weight of CaO found. grm.	Weight of CaO in 100 grams of solution. grm.	Mean.
(6.)	20·094	0·1133	0·5638	0·5633
(7.)	20·18	0·1136	0·5632	
(8.)	20·19	0·1135	0·5630	

My experiments began with analyses of solutions containing known quantities of the three substances. From this they grew and though the order may be the reverse of a logical one it had best be followed in giving the results.

In the first and second series the quantities of iron and calcium were constant, the manganese was variable. In a third series, containing only manganese and calcium, the proportions of each were varied.

The general mode of operating was the following:

The solutions, containing, in the first and second series, the equivalents of about 0·2 grams of iron and 0·17 grams of calcium oxide and quantities of manganese oxide varying from 0·03 to 0·2 grams, were diluted to 350–400$^{c.c.}$ To secure the usual conditions of analysis, and because ammonium salts tend to hold manganese in solution, 10$^{c.c.}$ of hydrochloric acid were added. The cold solution was neutralized with ammonia containing ammonium carbonate. The precipitate that might be formed was dissolved with as little as possible hydrochloric acid and 5· grams of ammonium acetate* added.

For the precipitation of the iron and the conversion of the salts of the other elements into acetates, this is an unnecessary excess and because of its possible reducing action on the iron, such an excess should in general be avoided. But, preliminary experiments having been made, it was believed that with proper care the reduction of the iron might be avoided. To further test this opinion and because of the influence of† ammonium acetate in holding manganese salts in solution, this excess was added.

Two acetate precipitations were made. The iron was thrown down a third time with ammonia. In but two cases (Nos. 14 and 17) did the third filtrate contain manganese. In making this separation care was taken not to digest the iron precipi-

* The ammonium acetate was prepared by neutralizing ammonia with acetic acid and an amount taken which would be equal to about 5 gr. of the salt.

† Experiments seemed to show that the influence of ammonium acetate in holding manganese salts in solution, though the solution be ammoniacal, is somewhat greater than that of the chloride of ammonium.

tate too vigorously nor too long and as a result there was in no case any appreciable reduction.

The filtrates from iron, being united, were evaporated to 400–500$^{c.c.}$, 10$^{c.c.}$ of ammonia, followed by 250–350$^{c.c.}$ of bromine water, were added to the hot solution, which was then heated on the water bath until the precipitate gathered leaving a clear colorless supernatant liquid. If digested over a direct flame the separation may be hastened.

The success of this precipitation depends largely on treating the solution hot. If bromine be added to a cold solution the oxidation is slow and often less complete. The addition of bromine to the solution already made ammoniacal seems preferable to a reversal of the order as it insures a more uniform oxidation.

Three bromine separations were made, the manganese precipitate being dissolved in hydrochloric and sulphurous acids. In no case did the third filtrate show calcium. The first and second filtrates from manganese were united. The volume was reduced to 300–400$^{c.c.}$ and the calcium was thrown down as oxalate and weighed as oxide.

The manganese was weighed as pyrophosphate. The iron was determined by the standard solution of permanganate.

The following are the results.

	Weight of Fe taken. grm.	Weight of Fe found. grm.	Weight of CaO taken. grm.	Weight of CaO found. grm.	Weight of MnO taken. grm.	Weight of MnO found. grm.
(9.)	0·2254	0·2251	0·1699	0·1690	0·0341	0·0355
(10.)	0·2248	0·2251	0·1700	0·1687	0·0680	0·0689
(11.)	0·2252	0·2248	0·1700	0·1696	0·1092	0·1094
(12.)	0·2251	0·2251	0·1700	0·1705	0·1500	0·1501
(13.)	0·2254	0·2253	0·1702	0·1697	0·2043	0·2053

Error in weight of	Fe grm.	CaO grm.	MnO grm.
(9.)	0·0003—	0·0009—	0·0014+
(10.)	0·0003+	0·0013—	0·0009+
(11.)	0·0004—	0·0004—	0·0002+
(12.)	0·0000	0·0005+	0·0001+
(13.)	0·0001—	0·0005—	0·0010+

Experience tells us, that in dealing with such precipitates as those of iron and manganese, repeated precipitation is necessary. In analyzing this necessity and determining its limitations a series of partial separations was made, and the quantities of manganese and calcium in each of the several respective filtrates was determined. The iron, of which about 0·22 grams was added in each case, was undetermined.

	Weight of Fe taken. grm.	Weight of MnO taken. grm.	Weight of MnO found in 1st filtrate from Fe. grm.	2d filtrate. grm.	3d filtrate. grm.	Total. grm.	Error. grm.
(14.)	0·2248	0·3341	0·0342	0·0005	none	0·0347	0·0005+
(15.)	0·2248	0·0678	0·0681	0·0006	trace	0·0687	0·0006+
(16.)	0·2250	0·1088	0·1073	0·0013	none	0·1086	0·0002—
(17.)	0·2252	0·1500	0·1477	0·0024	none	0·1501	0·0001+
(18.)	0·2253	0·2042	0·2003	0·0034	trace	0·2037	0·0005—

	Weight of CaO taken grm.	Weight of CaO found in 1st Fe filtrate. 1st Mn filtrate. grm.	2d Mn filtrate. grm.	2d Fe filtrate. grm.	Total. grm.	Error. grm.
(14.)	0·1700	0·1650	0·0025	0·0020	0·1695	0·0005—
(15.)	0·1700	0·1640	0·0044	0·0010	0·1694	0·0006—
(16.)	0·1702	0·1611	0·0074	0·0013	0·1698	0·0004—
(17.)	0·1700	0·1640	0·0038	0·0016	0·1694	0·0006—
(18.)	0·1701	0·1614	0·0059	0·0023	0·1696	0·0005—

In separating calcium from manganese in the first filtrate from iron three precipitations were made. In no case did the third filtrate contain enough calcium to show.

From the above analyses the necessity of two precipitations in separating manganese from iron and calcium from iron and manganese is evident. More than that seem superfluous.

In general the amount of manganese found in the second filtrate from iron is proportional to its total quantity. It frequently happens however that in neutralizing the solution, preparatory to the acetate separation, the manganese is precipitated and partially oxidized, in which case its resolution is impracticable. This oxidation is probably due rather to the action of the air than to any after effect of acetic acid. In separating manganese and calcium the completeness of a single separation seemed to depend, if anything was to be inferred from the above analyses, as well on the nature of the manganese precipitate as on its quantity.

It will be noticed that the manganese errors, with but one exception (16) are positive and the calcium errors, with one exception (12), are negative. This is to be anticipated. The positive error in the case of manganese comes from the use of a non-volatile precipitant. The negative error of calcium is probably owing to the fact that the oxalate is not absolutely insoluble.

The indications being that two precipitations are necessary, where the calcium and manganese are either or both present in quantities, a series of separations was made varying both

constituents. That the conditions of the previous analyses might be approximately kept, 5 grams of ammonium chloride and 10 grams of ammonium acetate were added in each case. Only the calcium of the first manganese filtrate was determined.

	Weight of MnO taken. grm.	Weight of CaO taken. grm.	Weight of CaO found in 1st filtrate. grm.	Loss. grm.
(19.)	0·2042	0·1702	0·1639	0·0063
(20.)	0·1020	0·1705	0·1638	0·0077
(21.)	0·0508	0·1702	0·1662	0·0042
(22.)	0·0207	0·1702	0·1682	0·0018
(23.)	0·2039	0·0848	0·0779	0·0069
(24.)	0·1020	0·0849	0·0831	0·0018
(25.)	0·0516	0·0855	lost	----
(26.)	0·0204	0·0846	0·0833	0·0013
(27.)	0·2037	0·0423	0·0399	0·0024
(28.)	0·1023	0·0427	0·0421	0·0006
(29.)	0·0512	0·0424	0·0415	0·0009
(30.)	0·0203	0·0428	0·0421	0·0007
(31.)	0·2037	0·0171	0·0141	0·0030
(32.)	0·1023	0·0173	0·0158	0·0015
(33.)	0·0509	0·0170	0·0167	0·0003
(34.)	0·0207	0·0171	0·0162	0·0009

These results indicate that the amount of calcium, carried down with the manganese, depends largely on the relative quantities of manganese and calcium. However this may be it is evident that where the amounts of each are not less than 0·02 grams a double precipitation of manganese should be made.

Having introduced such large quantities of ammonium salts into the solutions the question of effect on the oxalate precipitate was raised. Attention has been called to the negative calcium error. Is this due simply to the solubility of the oxalate or is it the sum of large positive* and larger negative errors?

In answer to this suggestion a number of calcium determinations were made, in which the previous conditions, as to quantity of ammonium salts and volume of solution, were observed.

* The source of positive error would be the reagents and glass ware. The operations, excepting the precipitation of manganese by bromine, were carried on in platinum. The ammonium hydrate and sulphurous acid were freshly prepared. The other reagents were carefully tested.

	Weight of CaO taken. grm.	Weight of CaO found. grm.	Error. grm.
(35.)	0·1136	0·1131	0·0005—
(36.)	0·1138	0·1135	0·0003—
(37.)	0·1136	0·1136	0·0000
(38.)	0·1139	0·1137	0·0002—
(39.)	0·1136	0·1132	0·0004—
(40.)	0·1138	0·1133	0·0005—

The solutions 300$^{c.c.}$ contained approximately 5 grams of the chloride, 5 grams of the acetate and 10 grams of the bromide of ammonium. The inference is that their influence in restraining the oxalate precipitation is slight.

Summary: In precipitating iron as basic acetate it is probably better to avoid a great excess of the acetate. A considerable excess need not however interfere with the separation. While an acetate solution favors the reduction of iron, with care this reduction may be avoided. The precipitate should not be digested too vigorously nor too long.

In neutralizing the solution, preparatory to the acetate separation, a slight precipitate of manganese, due to oxidation, is almost always formed. This influences more or less markedly the completeness of a single separation. It cannot be wholly avoided, though the effect of the presence of ammonium salts, in holding manganese salts in solution, is probably beneficial. While the manganese remains in solution oxidation cannot take place.

In precipitating manganese from an ammoniacal solution by means of bromine the presence of acetates is desirable. The oxidation is more rapid, hence more complete than in a solution free from acetates. Bromine water should be added to the hot ammoniacal solution. If the solution be cold the oxidation is slow and in the end often incomplete. The addition of bromine to the solution already made ammoniacal seems preferable to a reversal of this order as it insures a more uniform oxidation.

Where either the calcium or the manganese is in excess of 0·02 grams two precipitations are necessary.

In conclusion it may be said that, in the hands of a careful analyst, both methods are, according to present standards accurate.

Chemical Laboratory, Trinity College,
Hartford, Nov., 1891.

Art. XVIII.—*The Central Massachusetts Moraine;** by Ralph S. Tarr.†

Upon the plains of the Central States the ice of the last glacial period has registered, with distinctness, the various halts in its recession. The record of the ice retreat in this region has been worked out in admirable detail by the glacialists in charge of this work. Rapid retreats, temporary halts and slight readvances are here indicated by the glacial deposits.

The disappearance of the ice from New England must have been marked by very nearly the same history, but the detailed record of this retreat has not yet been studied. This is due in part to the fact that until recently no systematic studies of the glacial deposits of New England have been undertaken, but chiefly to the fact that the record left by the ice, as it melted away, is obscure. This obscurity is the result of the topographic diversity of the region. Upon a plain a slight moraine becomes a marked topographic feature, but amid the hilly district of New England its importance is masked by the more striking undulations and reliefs. In addition to this the very fact of the diversified topography has made the minor moraines actually less distinct and hence more difficult to study than would have been the case on a level country. The ice margin must have conformed in a measure to the topography, and hence the deposits must have varied in distribution with the variations in altitude and relief. Not only was their distribution so influenced but also their character. The rapid water currents rendered possible in a hilly country swept away portions and modified others.

For several years Prof. N. S. Shaler has been conducting detailed studies of the glacial deposits of Massachusetts and the neighboring states and eventually, if his plans are carried out, the record of the ice retreat in this region will be definitely known. As an assistant in this work during several summers it was my fortune to find and trace out, in part, a distinct morainal band in Central Massachusetts, marking a temporary halt in the recession of the glacier, and it is this that I shall briefly describe.

On the islands off the southern coast of New England a well defined terminal moraine has long been known and well de-

* Published by permission of the Director of the United States Geological Survey.

† I am indebted to Prof. J. D. Dana and Mr. Warren Upham for valuable suggestions which have aided in the preparation of this paper as well as to Prof. N. S. Shaler, under whose direction the field work, upon which these results are based, was done.

scribed by various observers. It seems to be established that this moraine marks the point of the glacier for the greater part of its long stand upon this part of the continent. Patches of morainal matter have been noticed and described from various parts of New England, by Mr. Upham and others, but no continuous lines of moraine have been traced for any considerable distance. Some of these morainal patches have been supposed to mark local glaciers remaining upon the higher lands after the main ice mass had disappeared.

A singular morainal area was described by Prof. Shaler in the Ninth Annual Report of the U. S. Geological Survey, as occurring at Cape Ann on Massachusetts Bay. As an assistant in this work my attention was called to this deposit several years ago and its boundary within the area was traced with considerable accuracy. At that time it was not known that this bit of moraine was connected in any way with any other, but subsequent studies of the glacial deposits have pointed to a somewhat continuous moraine from Cape Ann nearly to the Connecticut River. Beyond the Connecticut morainal deposits have not been identified with certainty, excepting in some of the larger stream valleys; and the connection of these apparently isolated moraines with the Central Massachusetts moraine has not been definitely established.

The Cape Ann moraine has been fully described by Prof. Shaler,* with numerous illustrations from photographs. In general it occupies a large part of the island of Cape Ann and of the mainland to the west and southwest. On the island it covers the major part of the interior, but is rarely found in perfect development below the one hundred foot contour line, this part of the island being chiefly bare bed rock as if wave-swept. The morainal boundary is roughly circular, with an average diameter of not more than four miles. It is completely separated from the moraine on the mainland to the westward by the inlet or "reach" of "Squam River," but above the one hundred foot contour line it begins again occupying a wooded strip, with a width of from one to four or five miles, in the towns of Manchester, Essex and Gloucester. Farther still to the west the moraine becomes narrower but is distinctly traceable in the vicinity of Chebacco Pond, Wenham, and farther west to the extreme boundary of the Salem sheet of the Massachusetts topographical atlas.

This band of moraine is twenty miles long, and the width varies from a few hundred yards west of Wenham to four or five miles east of that town. The average width is not less than a mile. From the western part of the Salem street to

* Ninth Annual Report U. S. Geol. Survey, pp. 529–611.

Ayer Junction, a distance of twenty-four miles I have had no opportunity for studying the surface geology, but just southeast of Ayer Junction distinct morainal deposits are found and a quite continuous band of moraine extends from here westward to the Connecticut river, passing south of Winchendon, Royalston, Orange and Turner's Falls. This line of moraine is fifty miles long and thus from Cape Ann to the Connecticut, a distance of ninety-four miles, moraine has been found in seventy miles, the remaining twenty-four not having been examined.

To briefly describe the Cape Ann moraine it may be said that the essential features are sharp peaks and hummocks of drift, completely enclosed kettle-holes of unstratified drift, and a surface thickly strewn with bowlders chiefly of granite locally derived. While the entire surface is bowlder strewn, the most excessive development of bowldery deposits is in trains, or parallel bands extending a little north of east at right angles to the direction of glacial motion. There are several square miles of such bowldery places on Cape Ann where the bowlders are literally piled one upon another with rarely any soil showing. A better development of the "bear-den" moraine would be difficult to find. Parallel with these bowlder lines are ridges of drift and the corresponding valleys.

While the material composing the moraine is considerably less clayey than ordinary till it is, with rare exception, an unstratified deposit quite closely resembling till. A few patches of stratified drift and a single serpent kame occur on the island.

On the mainland west of Cape Ann much the same character marks the moraine, except that bowlders are less numerous, as long as the moraine rests on the granite. Where it is found upon the metamorphic rocks as in Wenham and westward the bowlders decrease perceptibly in abundance and size, the deposits are more sandy and they merge more commonly into stratified deposits. At the same time the distinctly "shoved" moraine narrows. These facts are undoubtedly to be referred in part to the change in character of supply, but chiefly to the more moderate relief which permitted the deposition of sand and gravel deposits. Some of the morainal peaks are partly buried beneath such deposits.

In the region between Ayer Junction and the Connecticut River the morainal accumulations are quite puzzling. The country is hilly and deeply scored by both east and west and north and south valleys. The result has been a complicated distribution of the morainal deposits which renders exact statements concerning the detailed history of their formation quite

impossible at present. The distribution is in more or less continuous patches; but distinct lines of moraine cannot be traced for any considerable distance, their continuity being interrupted by the irregularity of the topography. As the result of this we find a series of scalloped, serrated lines in the general moraine. These lines and the entire moraine are sometimes broken, yet the general continuity of the deposit is undoubted, for the breaks are rarely a mile in length.

A vacillating condition at this place is indicated by the great width of the morainal deposits. The moraine-covered tract is often eight or ten miles in width and isolated patches of "shoved" moraine are found both to the north and south of this.

The central Massachusetts moraine is typically developed at Winchendon, Gardner, and south of Athol and Orange on the Winchendon and Warwick sheets of the Massachusetts topographical map. A detailed description of the moraine on the various sheets will be found in Prof. Shaler's forthcoming monograph on the Surface Geology of Massachusetts. It presents all the features of a typical "shoved" moraine, being rough in outline and bowlder strewn, having hummocks and kettles of unstratified drift and being associated with stratified drift both of contemporaneous and subsequent origin. This stratified drift is of the sand plain, esker and valley drift types. In places the morainal hummocks are made up of roughly stratified layers of till and gravel, they are at times partly and even entirely covered by stratified drift of the overwash type, and sand plains are not uncommonly found amid the morainal peaks and kettles. No distinct frontal apron exists, for the diversity of the topography would not admit of such well defined level deposits.

These observations prove that the ice halted in its retreat from New England at about the line occupied by this moraine. The halt was not of sufficient duration to permit of the formation of a strikingly well defined moraine yet it was long enough for the formation of a well defined morainal band. The varying width in the central part of the State points to some vacillation in the ice front at this place, though this does not seem to have been the case in the eastern part of the moraine near the coast line.

One of the striking features of the central Massachusetts moraine is its east and west course, since its linear extension is in general direction slightly diagonal to the glacial striæ. This is particularly the case in its sea coast end where it can be traced continuously for a score of miles nearly due west, whereas the striæ point usually N. 25 W. or even more. Even

in the interior the moraine does not swerve to the southwest showing that the highlands of the northern central part of the State and of New Hampshire exercised little influence upon the ice front. It may be said, however, that the glacial striæ in this part of the State point nearly north and south, the southeasterly trend near the sea coast being very likely due to the influence of the easterly sloping coast border.

Since this moraine has not been traced west of the Connecticut nothing can be definitely said with regard to its westerly continuation. It seems probable, as suggested to me by Prof. Dana, that the influence of the very marked highland region of the Berkshire Hills in Western Massachusetts must have caused a southward extension of the ice margin west of the Connecticut. In the region about Pittsfield and North Adams, particularly in the larger valleys, there are patches of bowldery, hummocky, partially stratified drift which seem to be morainal in character. No attempt can be made to correlate these with the central moraine at this time.

It is hardly probable that between the Long Island moraines and that of central Massachusetts the recession of the ice was so uniform and rapid that no sign of its retreat was left and the facts in the field seem to show that this was not the case. My studies have been in the main in isolated districts in Massachusetts, Connecticut and Vermont, so that aside from the moraine just described it is not possible for me to state definitely that other bands of moraine exist. Still, both south and north of this moraine, I have found isolated patches of true shoved moraine, though nowhere has it been found to have the well marked development noticed in that of central Massachusetts. Such deposits have been noticed in the vicinity of Worcester, Mass., in southeastern Massachusetts, Waterbury, Connecticut and southern Vermont, and other observers have described moraine in New Hampshire.

None of these deposits have been studied in detail and with a view to their relation to one another, but without doubt, when they are so studied it will be found that the history of the disappearance of the ice sheet from New England was, like the ice of the upper Mississippi valley, one of numerous halts and slight readvances, though the records left will be found to be much less distinct in New England than in the west.

ART. XIX.—*Proofs that the Holyoke and Deerfield Trap Sheets are Contemporaneous Flows and not later intrusions;* by BEN K. EMERSON.

IN the concluding paragraph of his most interesting article on the Trap Rocks about New Haven,* Professor Dana is inclined to make the results he has reached regarding the traps and sandstones of the New Haven region general for those of the whole Connecticut Valley.

He concludes that these traps are subsequent to and intrusive in the sandstones and not "poured out in one, two or more horizontal sheets, separated, and overlaid horizontally by beds of sandstone." The essential point in this contention, if I understand aright, is that the traps associated with the Triassic sandstones are all newer than these sandstones

The following is presented as an abstract of the proofs that all the main trap sheets in Massachusetts are contemporaneous flows, and easily distinguished from the smaller intrusive masses.

1. At the upper surface of the Deerfield bed of trap east of the mouth of Fall River opposite to Turner's Falls, a perfect ropy surface of flow is exposed and the soft red shale folds round the curved surfaces and into the deep grooves in a way only possible by a surface flow. The red sand can be picked out of open steam holes on the surface, as the bed is strongly vesicular at surface. At the base it is here aphanitic and the sandstone is baked into a black hornstone-like mass.

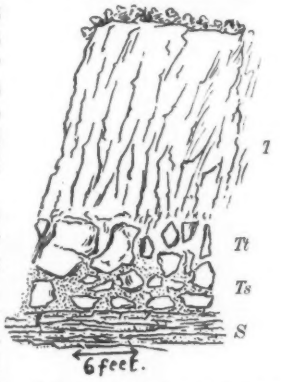
2. At the base of the same bed several miles south in the north edge of Greenfield, the cliff has been cleared at the City's Stone Crushing Works and a very remarkable section is exposed (fig. 1). The dip is east, and in the westward facing cliff the heavy trap bed, *T*, rests on soft unbaked sandstone, *S*, and is vesicular and coarsely brecciated for about 12 to 16 feet. The lower portion of this agglomerate, *Ts*, is cemented by a red sand which penetrates the fissures between the breccia blocks for six or eight feet up from the base and is now hardened to red sandstone, which is continuous below with the sandstone on which the trap rests, while an aphanitic non-vesicular trap is continued down between the coarse porous blocks, *Tt*, from the unbrecciated mass above to fill the fissures down to the point reached by the sand.

* This Jour., xlii, p. 110.

The explanation of this, I believe to be, that like an unrolling carpet the slaggy surface of the flow was underrolled on a submerged or muddy bottom and the mud was forced up into the fissures by the weight of the 200 feet of trap, and met in the cracks by the still liquid trap from above.

3. The Holyoke sheet from its east end to the Connecticut River bakes the sandstone on which it rests and has rarely large long steam pores running up from the base six inches or a foot, caused by the moisture in the subjacent sandstone, and it is highly vesicular and without any trace of baking at its upper surface.

1. Trap Section, Greenfield.



T, Trap; *Tt*, Trap agglomerate with trap cement; *Ts*, Trap agglomerate with sand cement; *S*, Sandstone.

Between the Connecticut and Westfield rivers (fourteen miles), the *base* of the sheet is often very vesicular and kneaded full of dove-colored limestone, as if limestone and trap had been plastic at the same time. In thin sections the fine grained limestone can be seen penetrating the steam holes with a distinct flow structure, but the boundaries are sharp between trap and sandstone. The trap is here perhaps 300 feet thick, but has not baked the subjacent arkose at all. At one place where the railroad between Westfield and Holyoke cuts the south line of the latter place a broad area of the *upper surface* of the sheet is filled in the same way with the same limestone to a depth of 8 or 10 feet. This latter rock is not in place in the rocks cut through by the trap, either at the surface or in the many artesian borings I have studied, down to 3500 feet in depth. I explain the above structure also by the underrolling of the surface of the sheet as above. A limited amount of calcareous mud was washed onto the submerged surface of the advancing sheet (which was superficially solidified) and blended more or less with this surface which by the continued advance of the mass became in part underrolled, thus protecting the sand below from baking, and bringing the highly vesicular trap loaded with limestone to the base of the bed.

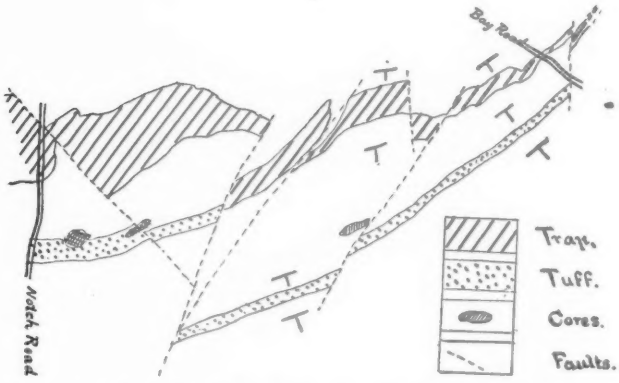
4. At the Delaney's Quarry by the railroad on the north line of Holyoke the extremely irregular surface of the trap which rises and falls twenty feet in the quarry and is warty and ropy in the extreme, is closely fitted by the dark mud at first deposited, and the sandy layers immediately above undulate in and

out of the depressions and slowly obliterate them, and all without marked induration. The trap immediately beneath is the finest amygdaloid. This is a portion of the posterior sheet.

5. The Holyoke sheet is covered by arkose and this by a thick bed of trap tuff and agglomerate whose outcrop stretches parallel to, and a mile south of, the main Holyoke sheet from its east end to Holyoke town, about eighteen miles.

I have cut many thin sections from all parts of this bed, and the diabase of which it is composed is not in any way to be distinguished from that of the main trap sheets here discussed. This makes certain the eruption of a great amount of trap during the deposition of the sandstones, and accords with the supposition that the closely associated Holyoke sheet was also contemporaneous with the sandstones. Fig. 2 gives a sketch

2.



of the east end of the Holyoke range and shows that the trap sheet and the tufa bed have been faulted together and that the main trap sheet must have found its present place in the sandstones below the tufa before the epoch of disturbance which caused this faulting, while the latter cores show generally a distinct connection with these faults.

Except the Holyoke and Deerfield beds, and the "posterior" trap sheet running across Holyoke town and Agawam, all the trap given on the small map recently published by me* is intrusive but is in small amount, and is in every way contrasted with the large beds discussed above. The intrusive trap sends out dikes in the sandstone in all ways. The smallest cores or dikes do much more baking than the thick beds because they have passed as hot lava through the sandstone while the beds have run as scoria-encased flows on the sands.

* Bulletin of the Geological Society of America, vol. ii, pp. 451–456, pl. 17.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Gravi-volumeter.*—An instrument by means of which the mass of a given gas is given directly from a single reading of its volume, has been devised by Japp, who has called it a gravi-volumeter. It is a modification of the gas volumeter of Lunge. The apparatus consists of two gas burettes, each of 50^{cc} capacity, provided with obliquely bored taps. One of these, A, has a three-way tap, and is used as the gas measuring tube; the other, B, has only a single tap and serves as the regulator tube. Both tubes are moistened internally, in order to saturate the gases they contain with aqueous vapor, and both are connected by means of stout flexible tubing and a T piece with the same movable reservoir of mercury. In calculating the "gravi-volumetric values" of the different gases to be measured, the 25^{cc} division of the regulator tube is taken as the starting point. In the case of nitrogen, for example, the volume to which 25^{cc} of standard-dry nitrogen must be brought in order that 1^{cc} may correspond with one milligram of the gas, is calculated. Since the mass of 25^{cc} of nitrogen is $0{\cdot}001256 \times 25 = 0{\cdot}0314$ gram, or 31·4 milligrams, this mass must be brought to $31{\cdot}4^{cc}$. The division 31·4 on the regulator tube is therefore marked N_2. Similar points are determined for other gases and marked O_2, CO_2, etc. The barometer and thermometer are now read, the volume which 25^{cc} of standard-dry air would occupy at this pressure and temperature is calculated, and this volume of air is admitted into the regulator tube. Suppose it is desired to ascertain the mass of a quantity of nitrogen contained in the measuring tube. It is necessary only to raise or lower the mercury reservoir until the mercury in the regulator tube stands at the nitrogen mark, 31·4, this regulator tube being adjusted so that the mercury level in it and in the measuring tube is the same. Under these conditions each cubic centimeter of nitrogen in the measuring tube has the mass of one milligram; so that the reading of the gas volume in cubic centimeters and tenths gives at once the mass of the gas in milligrams and tenths. By bringing the mercury in the regulator tube to the proper level, the mass of any other gas may be read in a similar manner. If it be brought to the 25 mark, the gas or mixture of gases will have the volume it would occupy in the standard-dry state and the apparatus acts as a gas-volumeter.—*J. Chem. Soc.*, lix, 894, November, 1891. G. F. B.

2. *On the Element Fluorine.*—An extended memoir upon the element fluorine has been published by Moissan, giving the results of his more recent researches upon this substance. An excellent resumé of this paper has been given in English by Tutton. For preparing the fluorine the platinum U-tube employed in the later experiments was much larger and had a

capacity of 160cc. It was immersed during electrolysis in boiling methyl chloride, giving a temperature of — 23°. In this tube a mixture of 100cc hydrofluoric acid and 20 grams HKF_2 was contained; and this under the action of 26 to 28 Bunsen cells arranged in series, evolved four liters of pure fluorine per hour. The gas as evolved was first conducted through a platinum spiral placed in a bath of boiling methyl chloride and maintained at about — 50°, for the purpose of condensing the accompanying hydrogen fluoride, which boils at 19·5°. It was then passed through platinum tubes filled with fragments of fused sodium fluoride, by which the last traces of the hydrogen fluoride were removed. At the beginning of the electrolysis the fluorine attacks the positive electrode, which is of pure platinum, producing PtF_4. This apparently unites with the potassium fluoride to form $(KF)_2PtF_4$; and it is only when the liquid contains this double salt that the electrolysis proceeds regularly. Pure fluorine possesses an odor resembling that of a mixture of hypochlorous acid and nitrogen peroxide; though this odor is masked by that of the ozone formed by its action upon moist air. In a thickness of one meter it has a greenish yellow color, paler and more yellow than that of chlorine; but its spectrum shows no absorption bands. Its spark spectrum shows 13 bright lines in the red between $\lambda = 0{\cdot}744^{\mu}$ and $0{\cdot}623^{\mu}$. Its density, as the result of many experiments, appears to be 1·265, the theoretical value being 1·316. It is not liquefied at — 95° at the ordinary atmospheric pressure. Fluorine combines with hydrogen with explosion, even in the dark and at a temperature of — 23°. With oxygen, on the other hand, it does not unite even at 500°. When fluorine acts on water a peculiar odor is noticed, which soon passes into that of ozone and which the author thinks may be due to an oxide of fluorine. Many other reactions are given in Moissan's paper.— *Ann. Chem. Phys.*, VI, xxiv, 224, Oct., 1891; *Nature*, xliv, 622, Oct., 1891. G. F. B.

3. *On the commercial production of Ozone.*—In a recent lecture by FRÖLICH he has given an account of the experiments which have been made in the laboratory of Siemens and Halske in Berlin for the commercial production of ozone. The original Siemens ozonizing tube consisted of two concentric glass cylinders, the inner one coated interiorly and the outer one exteriorly with metal; these two coatings being supplied with an alternating current of high potential, while oxygen was made to traverse the annular space between them. It now appears that only one dielectric is necessary, mica, celluloid, porcelain and the like being available as well as glass, and the ozone-tube having either a metal tube within and a metal-coated non-conducting tube without, or a metal tube without while the inner tube is made of the non-conducting material and lined with metal. The metals to be used are of course those which are not attacked by ozone, such as platinum, tin or aluminum. Cold water flows through the inner tube, and through the annular space pure dry air. Several such

tubes may be combined into one system and worked with alternating currents; though for single tubes a continuous current with an interrupter is best. The apparatus now at work in the above laboratory yields 2·4 milligrams of ozone per second. Experiments are in progress looking to the production of a supply of compressed ozone for technical uses; this having already been done on the small scale under a pressure of nine atmospheres. One use specially dwelt upon by the lecturer is that for the disinfection and sterilization of water.—*Nature*, xlv, 39, November, 1891. G. F. B.

4. *On Free Hydroxylamine.*—Free hydroxylamine NH_2OH, has at last been isolated by LOBRY DEBRUYN. For this purpose he heated about a hundred grams of hydroxylamine hydrochlorate dissolved in 600^{cc} of warm methyl alcohol, with such a quantity of sodium, also dissolved in methyl alcohol, as was necessary to leave the hydrochlorate in slight excess. After removing the sodium chloride by decantation and the methyl alcohol by distillation at 160–200^{mm} pressure, the residue was treated with anhydrous ether to completely precipitate the last traces of the sodium chloride. The liquid separated into two layers, the upper one being the ether, containing about 5 per cent of hydroxylamine, and the lower containing over 50 per cent, besides the remainder of the methyl alcohol. On subjecting this lower layer to fractionation under 60^{mm} pressure, three products were obtained, one containing 27 per cent of hydroxylamine, one 60 per cent, and the third crystallizing in the ice cold receiver in long needles and being pure hydroxylamine, NH_2OH. It is very hygroscopic and fuses at 33°, the liquid having a remarkable power of dissolving metallic salts. It is without odor and is heavier than water. It explodes violently when heated to 80–100°. It is only slightly soluble in liquid carbon compounds such as chloroform, benzene, carbon disulphide and the like. It readily attacks cork and cellulose. The pure crystals are very stable. Bromine and iodine act upon free hydroxylamine, the former with violence.—*Recueil des travaux chimiques des Pays Bas*, x, 101, 1891; *Nature*, xlv, 20, November, 1891. G. F. B.

5. *On Iron Carbonyls.*—MOND and LÄNGER have continued their researches upon the volatile compound of iron and carbonyl discovered by them in the first half of the present year.* For its preparation, they now prepare first finely divided iron by heating ferrous oxalate in a current of hydrogen, boiling the resulting product in water, and again heating the iron in a current of hydrogen. The hydrogen after cooling is displaced by carbon monoxide and the tube is closed at one end the other being connected to the source of supply of the carbonyl, this gas being slowly absorbed by the iron. After twenty-four hours, the iron-carbonyl is distilled off, the receiving tube being cooled to −20°, and the operation is repeated. The yield is small, only one gram being obtained from 100 grams of iron. As thus ob-

* See this Journal, III, xlii, 424, November, 1891.

tained iron-carbonyl is a somewhat viscous liquid of a pale yellow color. Its specific gravity at 18° is 1·4664. Under a pressure of 749^{mm} it distills without decomposition at 102·8°; and it solidifies below −21° yielding a mass of yellowish needle-shaped crystals. On exposure to the air it is slowly decomposed, yielding ferric hydrate. At 180° it is decomposed into iron and carbonyl. Its vapor-density is 6·4 to 6·5; corresponding to the formula $Fe(CO)_5$ which requires 6·7, while $Fe(CO)_4$ requires 5·7. Hence the authors propose for it the name ferro-pentacarbonyl. It is isomeric with ferrous croconate C_5FeO_5. When exposed to the light for several hours in a sealed tube this substance yields tabular gold-colored crystals, which when dry have a metallic luster and resemble flakes of gold. On analysis figures were obtained agreeing with the formula $Fe_2(CO)_7$ diferro-heptacarbonyl.—*J. Chem. Soc.*, lix, 1096, December, 1891. G. F. B.

6. *On the Presence of Iron-Carbonyl in Water Gas.*—In the course of some experiments upon a water-gas containing about 40 per cent of carbon monoxide, ROSCOE and SCUDDER noticed that the magnesia combs placed over the flame of the burning water gas became rapidly coated with iron oxide which materially decreased the illuminating power. Steatite burners were found to be stained with iron oxide in the same manner. When allowed to accumulate, the deposit took a coralloid, tuberous form, quite different from that assumed by particles mechanically transported. Suspecting the formation of iron-carbonyl, they compressed the water-gas in iron cylinders to eight atmospheres and allowed it to stand for a week. The gas, which usually burned with a blue non-luminous flame now burned with an intense yellow one and deposited upon the magnesia comb held in it large quantities of iron oxide. On depressing the lid of a porcelain crucible upon the flame a black stain of metallic iron was obtained; and on passing it through a heated tube a mirror of this metal was produced. Thirty liters of the compressed gas gave 32 milligrams of metallic iron when heated in a tube in this way. A plug of cotton wool placed between the heated portion of the tube and the burner received 40 milligrams of iron, in addition. On cooling the gas a liquid condensed having the properties of iron-carbonyl. Ordinary coal gas compressed in iron cylinders has been found to deposit iron upon the lime cylinders used in lantern projection.—*Nature*, xlv, 36, November, 1891.

G. F. B.

7. *An Introduction to Chemical Theory.* By ALEXANDER SCOTT, M.A., D. Sc. 12mo, pp. viii, 266. London and Edinburgh, 1891. (Adam and Charles Black).—The object of this excellent little book is to supplement those chemical text books which "are occupied too fully by the mere enumeration of facts and descriptions of experiments, to the exclusion of the more philosophical parts of the subject." The mode of treatment is original, the chapters on the "Constitution of Matter," on "Atomic and molecular Weights," on "Classification of the Elements," on "Abnormal

Vapor Densities and Dissociation," on "Thermo-chemistry" and on "Chemical change" being especially satisfactory. We cordially commend the book to those students who desire to acquaint themselves with the modern philosophy of chemistry.

G. F. B.

8. *Experiments arranged for Students in General Chemistry.*—By EDGAR F. SMITH and HARRY F. KELLER. 2d. Ed. Enlarged. 8vo, pp. 60. Philadelphia, 1891 (P. Blakston, Son & Co.). "This little work," say the authors in their preface, "is designed for beginners in chemistry." It describes carefully and precisely such experiments as the student can make himself, illustrated with cuts of the apparatus needed. It appears to us admirably adapted to its purpose. G. F. B.

9. *A Text-book of Elementary Chemistry.* By GEORGE F. BARKER, M.D. 2nd Edition, 1891. (John P. Morton & Co., Louisville, Ky.) There are not a few among our teachers of chemistry who believe that in schools of applied science and medicine, where chemistry is taught as a collateral subject, and in required courses in colleges, where but a limited time can be allowed for the acquisition of the principles and facts of this science, the inductive method of instruction is impracticable, and it is partly because of this belief and partly because Dr. Barker's work was admirably arranged, its statements were clear, accurate and concise, and the system of nomenclature and notation adopted were judiciously chosen from among the many then competing for recognition, that the first edition of his Elementary Chemistry owed the gratifying success which it achieved and has maintained since its publication in 1871.

This approval has made it seem undesirable in preparing a second edition to alter materially the general plan of the book other than results from the adoption of Mendeléeff's periodic law as the basis of its classification of the elements and for the arrangement of the descriptive part of the book; the use of the laws of thermo-chemistry in the elucidation of chemical phenomena and in tracing the connection between matter-changes and energy-changes; and the substitution of the word mass for weight in the terms "atomic weight" and "molecular weight" by which greater precision of statement is effected and the terminology of chemistry is brought into entire accord with that of the rest of the physical domain. Besides this the book has undergone a thorough revision; the newer discoveries in physical chemistry, such as the liquefaction and solidification of the gases and the many other physical constants being recorded from the data of the most recent experiments. Notwithstanding the considerable amount of new matter added, the size of the book has not been materially increased, as in the author's judgment a text-book should contain no more matter than the student may be required to master. C. E. M.

10. *Low Temperatures.*—Professor PICTET has established in Berlin a laboratory for work with low temperatures. In order

to avoid the great pressure required in handling the highly evaporative substances of lowest boiling point which serve to produce extreme cold, it is necessary to divide the difference of temperature into several stages. Each stage is fitted with especial apparatus consisting of an air pump worked by steam, which drains off the vapors of the liquid from the refrigerator, and forces them into a condensor where, reduced to the liquid state, they are again offered for evaporation in the refrigerator. Thus the liquid, without leakage, passes through a continuous circuit, and the operations can be carried on for any length of time. The liquid made use of for the first stage is a mixture of sulphurous acid and a small percentage of carbonic acid and is called "Liquide Pictet." It is condensed at a pressure of two atmospheres in a special tube cooled by running water. Oxide of nitrogen is the liquid chosen for the second stage. Its vapors are condensed in the same way, at a pressure about five or six times as great in a tube maintained at about $-80°$ C. by the action of the first circuit. As a medium for a third stage in which continuous circulation has not yet been attempted, atmospheric air is employed, which passes into the liquid state at a pressure of about 75 atmospheres, provided the condenser is kept at $-135°$ by the first two circuits. The evaporation of the liquefied air causes the thermometer to fall below $-200°$. A remarkable difference has been noted in the radiation of heat by Prof. Pictet. Material considered a non-conductor of heat does not appear to affect much the passage of heat into a body cooled down below $-100°$. In Professor Pictet's words the slow oscillations of matter, which constitute the lowest degrees of heat, pass more readily through the obstructions of a so-called non-conductor, than those corresponding to a higher temperature, just as the less intense undulations of red light are better able to penetrate clouds of dust than those of the blue. The quantity of heat which hourly floods a cylinder 1250^{mm} high by 210^{mm} wide (the size of the refrigerator) at $-80°$, is no less than 600 calories, and no packing will keep it out. At a lower temperature, the radiation being even greater, the power of the machinery intended to draw off still more heat would have to be enormous. The lowest temperature Prof. Pictet judges to be attainable is about $-255°$. In order to measure the elasticity of mercury, Prof. Paalzon had the metal cast and frozen in the shape of a tuning fork. Professor Pictet by freezing chloroform has refined it so that it becomes a stable substance.—*Nature*, Nov. 12, 1891.

J. T.

11. *Vibrations of Strings.*—Menzel and Raps have studied this subject by the aid of photography. The light of an electric lamp is thrown by means of a slit and a combination of lenses upon the vibrating wire or string. The image of the slit is at right angles to the string. A chronograph cylinder is placed behind the vibrating string. This cylinder is covered with sensitive paper. When the string is at rest and the cylinder revolves, a dark band is photographed on the paper with a white

line passing through its middle, caused by the shadow of the string when it crosses the slit. When the string vibrates this shadow draws, so to speak, the vibration of the string on the sensitive paper. A large number of results accompany the paper. The effect of bowing the string near the nodes, is discussed.—*Ann. der Physik und Chemie*, No. 12, 1891, pp. 623–641. J. T.

12. *The Telephone as an optical instrument for current measure.*—M. Wien affixes a stylus to the diaphragm of a telephone. This stylus touches a mirror which is fastened to a flexible arm, which in turn is clamped in an adjustable support. The mirror holder is tuned carefully to the note of the diaphragm and the latter is also tuned to the note of the alternating current which is employed. The instrument readily shows $3 \cdot 10^{-7}$ amperes.—*Ann. der Physik and Chemie*, No. 12, 1891. pp. 681–688. J. T.

13. *Solubility of Glass.*—F. Kohlrausch has completed an exhaustive paper on this subject. Among the large number of results obtained by him, it is noted that glass containing silicic acid, boracic acid, alkali without chalk, show little solubility. Borax glass without silicic acid is enormously soluble.—*Ann. der Physik und Chemie*, No. 12, 1891, pp. 577–622. J. T.

14. *An Introduction to the Mathematical Theory of Electricity and Magnetism;* by W. T. A. Emtage. 228 pp., Oxford, 1891. —This little volume gives an excellent introduction on the mathematical side to the subjects of Electricity and Magnetism, and will be very useful to the student who does not wish to plunge at once into one of the larger treatises. The method of presentation and the statement of definitions are very clear and systematic.

II. Geology and Mineralogy.

1. *Tenth Annual Report of the U. S. Geological Survey*, 1888–89.—J. W. Powell, Director. In this Report, the report of the Director and the Administrative reports of the Heads of Divisions, occupying 252 pages, are followed by three memoirs of great value, entitled: General account of the freshwater morasses of the United States, with a description of the Dismal Swamp district of Virginia and North Carolina, by Prof. N. S. Shaler, with plates VI to XIX; The Penokee Iron-bearing series of Michigan and Wisconsin, by R. D. Irving and C. R. Van Hise, with plates XX to XLVII; and The Fauna of the Lower Cambrian or Olenellus Zone, by C. D. Walcott, with plates XLVII to XCVIII.—A second volume of 123 pages constituting Part II. of the Report, is devoted to the subject of the Irrigation Survey.

Professor Shaler treats of the formation of morasses, and the conditions favorable to it in climate, vegetation and position, and enters into the history, geological structure and economic value of the region of the Dismal Swamp, illustrating the subject with many sections and fine plates. The paper by Professors Irving and Van Hise describes with fulness the rocks and structure of

the Penokee belt of iron-bearing and other beds, lying in Wisconsin, next south of the Keweenawan series. It is made the basis by them, along with the Keweenawan, of the pre-Cambrian division of rocks called "Algonkian;" but in the closing paragraph, it is stated, after remarks on the use of the term Huronian, that the Penokee series is properly Huronian, if the latter term is restricted to such water-deposited rocks as are proved to lie unconformably on a system of older crystalline rocks which are distinctively Archæan. The evidence of unconformability in the case of the Penokee series appears to have been worked out with great care. Many plates of rock slices, maps and stratigraphic sections, illustrate the paper. Mr. Walcott's memoir has been noticed in the last volume of this Journal.

In the course of the Administrative Reports, Professor Shaler states (p. 19) that he has discovered that the reefs of living coral on the east coast of Florida have not their limit at Cape Florida, as has been hitherto supposed, but extend many miles north; that a distinct reef continues probably 10 or 12 miles beyond Jupiter Inlet.

Mr. Arnold Hague reports (p. 134) the discovery of a new hot spring area, on the east side of the Yellowstone near the head of Wapiti Creek. He also states (p. 135) that orpiment and realgar have been found coating siliceous sinter in the Norris Basin, Yellowstone Park. Mr. G. F. Becker attributes (p. 142) the exterior form of the great granite domes of the Yosemite to exfoliation on a gigantic scale.

The U. S. Geological Survey has also issued many new Bulletins. No. 68, Earthquakes in California, by J. E. Keeler; No. 69, A Classed and Annotated Bibliography of Fossil Insects, S. H. Scudder; 71, Index to the known fossil insects, including Myriapods and Arachnids, idem; 72, Altitudes between Lake Superior and the Rocky Mountains. W. Upham; 73, the viscosity of Solids, C. Barus; 75, Record of N. A. Geology for 1887 to '89, N. H. Darton; 76, Altitudes in the U. S., 2nd. ed., H. Gannett; 77, Texan Permian and its Mesozoic type of fossils, C. A. White; 79, a late volcanic eruption in Northern California and its peculiar lava; J. S. Diller; 80, Correlation Papers, Devonian and Carboniferous, H. S. Williams; 81, Correlation Papers, Cambrian, C. D. Walcott; 82, Correlation Papers, Cretaceous, C. A. White; 91, Record of N. A. Geology for 1890, N. H. Darton.

2. *Stratigraphy of the Bituminous Coal Field of Pennsylvania, Ohio and West Virginia;* by ISRAEL C. WHITE. Washington, 1891. Bulletin No. 65 of the U. S. Geological Survey.—This admirable memoir by Prof. White deserves more than the passing notice usually assigned to such papers. It is an attempt to correlate the groups and individual coal beds, which is so far successful as to challenge respect from all who have spent much labor within the area discussed. This bulletin is no mere compilation of old work done by Prof. White and others; it is an actual revision of all that has been done, a great part of the

region having been re-examined. Prof. White deals with the Coal Measures only, of which, in accordance with the Pennsylvania classification, he recognizes five groups, beginning with the Pottsville Conglomerate, XII, and ending with the Permo-Carboniferous, XVI. Each of these groups is the subject of a chapter, of which the first part gives a large number of measured sections to prove the relations of the group, while the second part describes in detail the variations of the several strata. Much of the material is wholly new, nearly all of that relating to West Virginia being published now for the first time. The gathering together of the salient facts from the Pennsylvania reports was a serious labor, for which we should be deeply grateful. Prof. White has been generous in recognition of his fellow-laborers, sometimes overlooking his own work and assigning credit where no credit is due. J. J. S.

3. *Age of the Plants of the American Trias.*—Mr. LESTER F. WARD, in a review of the plants of the American Trias, (Bull. Geol. Soc. Amer., iii, 23, 1891) arrives at the conclusion that present knowledge fixes the horizon of the formation "at the summit of the Triassic system;" and also that the beds of Europe, "which seem to be most nearly identical so far as the plants are concerned, are those of Lunz in Austria and of Neue Welt near Basle in Switzerland," which are referred "by the best European geologists to the Upper Keuper."

A paragraph on page 25 of the Bulletin of the Geological Society(page 3 of Mr. Ward's article) needs some correction. It reads: "Second, the New Jersey and Pennsylvania area, extending from the Hudson River to the Potomac. I have not used the term 'Palisade area,' which was employed by Professor Dana, because he makes this to include also the Triassic deposits of Virginia and even to embrace the Richmond coal-field."

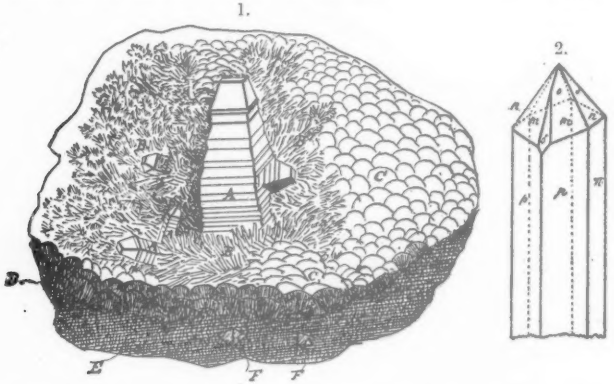
Prof. Dana is not aware that he ever made the Palisade area to include "the Triassic deposits of Virginia" of which there are several, or "even the Richmond Coal-Field." In the last edition of his Manual, on page 404, it is stated that the Palisade area extends from New York to Orange County, Virginia. [The same extension is given it in the colored geological map published in the 5th Annual Report of the U. S. Geological Survey (1885), as well as in earlier maps.] The termination in Orange County is nearly 50 miles northwest of the Richmond area. On the next page the Manual, describing the Triassic areas severally, states again the same limits, and makes the Palisade area No. 4, and the area near Richmond No. 5. The first edition of the Manual (1862) gives the same numbering of the areas and the same limits to the Palisade area.

4. *Chalk and flints at the Solomon Islands.*—Prof. LIVERSIDGE describes (Australian Association, 1890) chalk from Ulawa Island of the Solomon group, containing Foraminifera, but not so abundantly as a similar chalk described by him in 1877, from New Ireland. With the chalk were flints closely resembling those of

England; all were rolled specimens. Nothing organic was detected in the flint. He cites from Dr. Guppy's letters of 1883 that the flints of Ugi, another island of the group, are found in the soil. The prevailing rock of the island is an earthy foraminiferous limestone, and no flints were found in it.

5. *Paramelaconite and Footeite.*—Dr. G. A. KOENIG has recently described two new copper minerals which occur closely associated with each other upon a mass of cuprite and limonite. They were obtained by A. E. Foote from the Copper Queen mine at Bisbee, Arizona.

PARAMELACONITE occurs in steep pyramidal crystals (A, fig. 1.) terminated by the basal plane, the pyramidal faces are strongly striated; from the measured angle, $001 \wedge 111 = 58° 50'$, the vertical axis $c = 1{\cdot}6643$ is calculated. The hardness is 5, sp. gravity 5·833. Color purplish black, on the fracture pitch black. An analysis gave: CuO 100·58, Fe_2O_3 0·64 = 101·32, which is interpreted as: CuO 87·66, Cu_2O 11·70, Fe_2O_3 0·64 = 100. It is hence essentially CuO, like melaconite and tenorite, but is distinct in crystallization, and a relation in form to octahedrite is suggested.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by J. M. CLARKE. From Rept. State Geologist N. Y. for 1890, pp. 13, 3 pl.; 7, 1 pl.; 6, 1 pl. 1891.—These critical observations on *Acidaspis*, *Coronura*, and *Terataspis*, give important supplemental information to the previous knowledge of these forms. *Ceratocephala*, a name proposed by Warder in 1838, was the first distinctive term applied to any member of the well-defined group currently known as *Acidaspis*, and is taken as the leading genus. The author arranges the species in the following subgeneric groups: *Odontopleura* Emmrich, 1839, *Acidaspis* Murchison, 1839, *Ceratocephala* Warder, *sensu stricto*, 1838, *Dicranurus* Conrad, 1841, *Selenopeltis* Corda, 1847, *Ancyropyge* Clarke, 1891.

The fortunate discovery of an entire specimen of *Coronura aspectans* Conrad (sp.), terminates a long series of synonymical uncertainties. It gives a remarkable confirmation to the conclusion reached in vol. vii, Pal. N. Y., based upon fragmentary evidence, that the eye described by Conrad and the pygidia described by Hall and Meek belong to a single species. The author, moreover, considers this as included in an earlier name, the *Asaphus diurus* Green.

The restoration of a specimen of *Terataspis grandis* Hall, based on a large cephalon and on comparisons with other portions, gives a length of twenty inches. It consequently represents the largest individual trilobite known. The species had a highly differentiated defensive armor, which with its great size made it one of the dominant Paleozoic invertebrates. C. E. B.

7. *Cretaceous fossils of Syria.*—R. P. Whitfield describes and figures a number of Syrian species in the Bulletin of the American Museum of Natural History for December, 1891.

8. *Annual Report of the Geological Survey of Arkansas for* 1890. Vol. II, *The Igneous Rocks of Arkansas*, by J. FRANCIS WILLIAMS, 457 pp., 8vo, 1891. John C. Branner, State Geologist.—This country affords no more interesting series of igneous rocks than the elæolite-syenites and related rocks of Arkansas, which Dr. Williams discusses with admirable thoroughness in this volume. It is at the same time a nearly new field, for though the many rare and interesting minerals, particularly of the Magnet Cove region, have been long known and often described, but little has been published in regard to the nature and occurrence of the rocks with which they are associated. Four regions are enumerated, in which these rocks occur: (1) that of Pulaski county or Fourche Mountain; (2) of Saline County; (3) of Magnet Cove and (4) the Potash Sulphur Springs. The Fourche Mountain rocks which are largely used for building purposes, include the "blue granite" here named *pulaskite*, a rock with trachytic structure consisting of orthoclase, biotite, hornblende with but little augite, elæolite, sodalite, etc.; also the "gray granite," or elæolite-syenite; further a variety of dike rocks; there are also certain augitic rocks to one of which—a kind of monchiquite (Rosenbusch)—the name *fourchite* is given, while a sub-group under this is called ouachitite. The most varied and interesting of the regions named is

that widely known by the name of Magnet Cove, where there is an extensive development of rocks of the elæolite-syenite type and with them certain remarkable leucititic dike rocks of very high interest. These contain large crystals, sometimes nearly an inch across, of pseudoleucite crystals now entirely altered to a mixture of orthoclase and elæolite, also elæolite, orthoclase, ægirite, pyroxene, biotite, etc. The author discusses these rare types of rocks with great fulness and also the various contact rocks and contact minerals of the whole region. The latter include those of the quartz and sandstone, as brookite, rutile, etc., also those of the calcite, including perofskite, vesuvianite, monticellite and others.

This volume of Dr. Williams is a model of careful, thorough work, honorable alike to the author and to the State, and its varied contents have been hardly more than hinted at in this notice. It gains an additional and melancholy interest from the fact that it was the chief and last work of its lamented author, who did not live to see it in complete form; it is stated that the disease which so abruptly closed his labors was contracted during the work in the field which is here recorded.

III. Botany and Zoology.

1. *On specific Assimilation in Umbelliferæ.*—M. Géneau de Lamarlière (Comptes rendus, July 27th, 1891), recounts the results of interesting experiments on leaves, conducted in the Biological Laboratory at Fontainbleau, under the direction of M. Gaston Bonnier. The Order *Umbelliferæ* presents good material for the comparison of the amount of assimilation in different leaves of the same area. The activity of assimilation in dissected leaves is appreciably greater than from the same surface of leaf in a single segment. This difference is uniformly correlated with the minute structure: dissected leaves in this order have two or more layers of palisade-parenchyma; while simple leaves and those having large segments possess only a single layer of parenchyma. In the case of linear divisions, the parenchyma is continued around the marginal nerve and tends to invade the lower face. The following table indicates the wide difference which exists in the amount of assimilative activity. The species first mentioned, *Angelica silvestris*, has large segments: the species compared with it has in each case smaller divisions of the leaves, but these are thicker.

			c.c.		c.c.		c.c.
I.	*Angelica silvestris*	1.	0·102	2.	0·112	3.	0·140
	Libanotis montana		0·159		0·166		0·240
II.	*Angelica silvestris*	4.	0·087	5.	0·091	6.	0·110
	Peucedanum Oreoselium		0·286		0·241		0·240
III.	*Angelica silvestris*	7.	0·068	8.	0·076	9.	0·084
	Peucedanum Parisiense		0·232		0·252		0·380

The numbers denote the amount of carbonic acid (expressed in cubic centimeters) absorbed in one hour. G. L. G.

2. *Effects of certain poisons on the germination of seeds.* CH. CORNEVIN (Comptes rendus, Aug. 3, 1891).—The author investigated the effect of a toxic extract of certain seeds upon the germination of the seeds of that species. For this series, Saponine, which abounds in *Agrostemma Githago*, and Cytisine, in the seeds of *Cytisus Laburnum*, were made to act for from six to forty-eight hours on the seeds of the respective plants, by the side of unpoisoned seeds used for control. These poisons did not hinder the progress of germination.

A second series was designed to determine the effects of poisons originating in some other part of the plant on the germination of seeds of that species. Nicotine from tobacco, and opium from the poppy were employed. Seeds of tobacco immersed in a solution of nicotine, 1 : 150, were retarded for 48 hours in their germination. On the other hand, opium appeared to hasten the germination of the seeds of the poppy, but further examination showed that the complex substance should be studied with reference to its constituents. Three alkaloids hastened the germination, namely, narcotine, codeine, and narceine; while two had no effect, morphine and thebaine; and one retarded the process, papaverine. G. L. G.

3. *Proofs of land-communication between Europe and America during the "modern" age of the earth.*—M. ÉMILE BLANCHARD (Comtes rendus, July 20, 1891), cites numerous examples of organisms common to the two continents, and appeals to these as proofs that the continents were formerly united together in a line drawn from Scotland through Iceland to Greenland. The plants which he enumerates are certain Anemones, *Cruciferæ*, Violets, Stellarias, numerous *Rosaceæ*, especially Spiræas and Potentillas. Further, are to be mentioned many Saxifrages, Epilobiums, and *Caprifoliaceæ*. *Scrophulariaceæ*, *Labiatæ*, *Borraginaceæ*, and *Gentianaceæ*, among herbs: Alders, Willows, and Junipers, and the Yew, among aborescent forms. It will be observed that M. Blanchard carries his list much beyond the ordinary limits of the boreal species common to both continents. There is nothing particularly new in the view expressed, but the illustrations are many and to the point. Besides the species of plants, he mentions a large number of insects, fishes, and quadrupeds, which exist in specific identity on both sides of the Atlantic. G. L. G.

4. *Comparative Anatomy of Plants.*—AD. CHATIN, in presenting to the French Academy the last fascicle of his histology of Phanerogamous Parasites, calls attention to the date of the beginning of his researches. The original Thesis was propounded in 1840, and the present work, based thereon, was begun in 1854. The parts have been issued at intervals ever since, and have maintained throughout a definite character of their own. A work covering so long a period, and developed under the diverse influences of different phases of scientific thought must always possess a peculiar historical interest. The author began his work when

there could not be said to be anything like a comparative histology, in our sense of the term, and it has been continued through years which have given to us, on every hand, contributions in every department of the subject. We can imagine, therefore, the satisfaction which the author takes now in noting the general results obtained by himself and by others who have worked in the same field, in establishing a comparative histology for technical and morphological ends. Even if the author did not inaugurate the movement, he has participated in it from the very outset.

G. L. G.

5. M. Lucien Daniel (Comptes rendus, Sept. 21, 1891), sums up the results of his experiments on root-grafting as follows:—(1) we can often obtain grafts on the roots of closely allied plants. (2) The graft may succeed without bringing the generative layers in contact. (3) Sometimes we can graft a plant on the root of another belonging to an entirely different family; *Saponaria* on an *Onagracea*, for example. (4) The lack of success in most cases can be explained by the obstacle which the membranes of the graft present to the passage of nutritive matters. G. L. G.

6. Two communications in recent numbers of Comptes rendus, are of considerable interest to vegetable physiologists, but of greater importance to Horticulture. Lechartier (Oct. 12, 1891), shows that the leaves of artichokes which turn yellow and then darker, fading away and wilting, towards the close of the season, yield up their food to the ripening parts in a very steady manner. Henri Becquerel (Oct. 19, 1891), gives the results of his examination of soil temperatures during the winter of 1890–91.

7. Bourquelot (Comptes rendus, Nov. 23, 1891), has examined the different parts of *Boletus edulis* and *aurantiacus*, with reference to the distribution of the nutritive matters therein contained. These fungi agree in this; they contain most of their food in the forms trehalose and glucose, mostly the former, in the stalk, and rim, and not in the so-called tubes. The foot or stalk contains about twice as much as the rim. G. L. G.

8. *Die natürlichen Pflanzenfamilien.*—This admirable treatise by Engler and Prantl, which has been often mentioned in this Journal, has now proceeded as far as Numbers 68 and 69. The typography is as good as at the outset, and the illustrations as excellent and abundant. The disorder attending the method of publication by detached numbers is likewise as great as at first, and leaves much to be desired. There seems to be no reason why a work of this high character should be marred by defects observable in cheap subscription books. There is, however, little doubt that the completed treatise will be, in every way, one worth waiting for. G. L. G.

9. *Work of Lobworms in bringing Sand to the Surface.*—Prof. Charles Davison, of Birmingham, England, in a paper published in the Geological Magazine of November, 1891, gives the results of his observations on the work of the Lobworms in the "Holy Island Sands," between Holy Island and the opposite

coast of Northumberland. His method of investigation was like that of Darwin on earthworms. His results show that while the earthworms studied by Darwin brought to the surface in four cases 14·58, 18·12, 7·56 and 15·1 tons per acre annually, the Lobworms bring up 136 times this amount in the same time. In his six trials he obtained per acre 901, 3146, 3147, 449, 396, 329 tons per acre. The average is 47,237 cubic feet annually per acre; which corresponds, after drying and pressing, to a layer 13 inches thick. The Lobworms burrow to a depth of 12 to 24 inches; and taking the higher figure, "the layer of sand in which they live must on an average pass through their bodies once in 22 months." Fresh sand is being continually placed by them within the wearing action of the sea. The surface over which they occur is inclined; and at the touch of the water, the casting sinks down and swells out at the base, more of it flowing down the slope than up. It thus loses its vermiform appearance and is changed to a low mound elongated downward or completely flattened out.

IV. Astronomy and Terrestrial Physics.

1. *Periodic Variation of Latitude.*—The observations of Dr. Küstner at the Berlin Observatory, published in 1888, indicated the surprising phenomenon of the variation of the geographical latitude of Berlin, to the extent of nearly, if not quite, half a second. This announcement was received by astronomers with considerable hesitation, and only the known accuracy of the methods of the Berlin Observatory, together with the established high reputation of the observer, secured for it the careful attention which its apparent improbability might otherwise have prevented. Various explanations were suggested: among them some possible difference between the atmospheric refraction north and south of the zenith: also, since the variation seemed to be an annual one, some influence connected with the changes of the seasons: also some imaginable systematic errors in the declinations of the stars employed, varying with their right-ascensions.

The International Geodetic Association deputed Prof Helmert, director of its Central Bureau, to arrange for concurrent action by various observatories for investigating the nature of the variations in question, a plan which was effectively carried out. An elaborate collection and discussion of more than 5000 latitude determinations was presented by Dr. Albrecht to the Association. The simultaneous observations at Prague and Potsdam gave results in perfect conformity with those made at Berlin, and it soon became manifest that the phenomenon was no local one, but that all the latitude-determinations at the several places gave accordant indications of simultaneous fluctuations in 1889 exceeding the half of a second. Later the hypothesis that the period of the variation was annual was disposed of by evidence that the various latitudes determined in 1890 were in general

smaller by about 0″·2 than those observed at the same season in 1889.

The well-known theoretical period of ten months, originally deduced by Euler, had been shown successively by Peters, Nyrén and Newcomb, after careful comparison of various series of observations, to manifest little or no trace of real existence. The supposed secular changes, on which Fergola, supported by Schiaparelli, had based propositions for further investigation, had similarly been shown by Prof. Hall to be questionable. Later, Radau and Helmert published researches, in which it was pointed out that, an epicyclical combination of the ten-months' period with one of several years' duration, commensurable with it, would give a resultant inequality of the latitude having a period of from eleven to fifteen months, and the particular character of which would depend on the coefficients assumed.

The observed variations of latitude might of course be explained by a change either in the position of the zenith or in that of the pole. To decide this question, as well as to confirm or disprove the assumption that the observed motion is common to the whole globe, the Geodetic Association equipped and sent out an expedition to establish a station at Honolulu, a point differing by about 180° in longitude from the region in which the German observations had already been made. The observer, Dr. Marcuse, was instructed to make continual determinations of the latitude, by Talcott's method, for a full year. And, that the determinations might be fully confirmed, the U. S. Coast and Geodetic Survey was invited also to send an observer, with another instrument, to the same place,—an invitation which an appropriation from the Bache fund of the National Academy enabled the Superintendent to accept. Accordingly he deputed Mr. Preston, an experienced assistant of the Survey, to make these independent determinations. Meanwhile the observations in Europe, were continued, and with mutually confirmatory results. Moreover Dr. Nyrén brought to the Astronomical Congress at Munich, in August last, a series of latitude-determinations made at Pulkowa, which exhibited variations closely parallel to those simultaneously made at the German observatories.

The original observations of Dr. Marcuse at Honolulu were sent to the Central Bureau at Berlin, in monthly installments, and were computed there. At the close of September last, three months' observations had been fully computed, and the result found that, while the changes were entirely accordant in magnitude with the European ones, they were in the opposite direction. This might at first be supposed to imply an actual tilting of the earth's axis, corresponding to a change in position of the celestial pole. But this appears not to be the case, for, although the distance between the zenith and the pole is thus seen to have diminished in one place, while it increased at the other, on the opposite side of the earth, the interpretation mentioned is excluded by the important fact that identical stars were employed for the

determinations at both places, and the observations therefore made at times differing by twelve hours. The inevitable inference is that the changes observed are not in the position of the celestial pole, but in that of the zenith; in short, that the phenomenon is not one of nutation, strictly speaking, but rather a change in the position of the terrestrial pole, affecting the geographical latitude of the point of observation.

In Nos. 248–251 of the Astronomical Journal are a series of articles by Dr. S. C. Chandler, giving the result of his later investigations of this periodical variation. In 1884, '85 he had made a series of determinations of the latitude of Cambridge, with his then newly invented instrument, the Almucantar. These showed a curious progression in the values obtained for the latitude, to which he called attention in the Astronomische Nachrichten as early as May, 1885. A continuation of the observations confirmed the phenomenon, and a new discussion of the whole, with this fuller material, has given almost identical results; and showed both a maximum and a minimum, as well as a period of about fourteen months. The further discussion of this, and various other series of observations in which similar unexplained anomalies had been found, led him to the general result that the earth's axis of figure is revolving around that of rotation, from west to east in a period of 427 days; so that one pole revolves about the other in a circle, the radius of which is about thirty feet.

After discussing various series of observations suitable for the purpose, Chandler has arrived at the conclusion that the adoption of this hypothesis affords the true solution of various discordances which have long perplexed astronomers. Incidentally he points out, as a probable result of the incorporation of this new anomaly in the latitude, that the value of the constant of aberration, now commonly employed in preference to Struve's, is likely to prove too large; and that Struve's value is nearer the truth. By a comparative discussion of simultaneous observations made at Melbourne, Leyden, Pulkowa and Washington, he demonstrates that the phenomenon is not simply local or regional, but is terrestrial. He furthermore shows that Bradley's zenith-sector observations, which originally led to the discovery of aberration and nutation, also reveal the effect of the periodic latitude-variation with remarkable distinctness, and finds that these, as also various other series, indicate that the period has, in general, been lengthening since the last century. But he infers that, so far as can be recognized at present, the lengthening of the period has not proceeded according to any regular law, but appears to a certain extent capricious; and moreover that there is some relation between the amplitude and the period of the variation.

In No. 251 of the same Journal Prof. Newcomb points out that the 427-day period is perfectly consistent with dynamic laws, since we may suppose the deviation from Euler's theoretic value to be due to imperfect rigidity of the earth and to the fluidity of

the ocean; the joint effect of these tending to produce an approach of the two poles and a lengthening of the period of rotation. He thinks that the modulus of the earth's elasticity, deducible from Chandler's period will probably prove consistent with that which Sir Wm. Thomson indicates as requisite, in order to account for tidal phenomena. B. A. G.

2. *Astronomy and Astro-Physics*, January, 1892. Editors: WM. W. PAYNE, Goodsell Observatory, Northfield, Minn., and GEORGE E. HALE, Kenwood Astro-physical Observatory, Chicago. —This new Journal is in part a continuation of the well known *Sidereal Messenger*, but with this is coupled a new department devoted particularly to spectroscopy and astro-physics. The first number, containing a variety of valuable and well illustrated papers, gives a highly favorable impression of this new periodical and promises much for its success in the future.

V. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Essays upon Heredity and kindred Biological Problems* by Dr. AUGUST WEISSMANN, Prof. Univ. Freiburg in Breisgau. Edited by E. B. POULTON, M.A., F.R.S., S. SCHÖNLAND, Ph.D., and A. E. SHIPLEY, M.A., F.L.S. Vol. I, 472 pp., 8vo. Oxford, 1891 (in New York, Macmillan & Co.).—The second edition of the English translation of Prof. Weissmann's remarkable essays is in course of publication and the first volume has just been issued. It contains the essays on the Duration of Life; on Heredity; on Life and Death; on the Continuity of the germ-plasm as the foundation of a theory of Heredity; on the number of polar bodies, and their significance in Heredity; on the supposed Botanical proofs of the transmission of acquired characters; on the supposed transmission of mutilations. The second volume will consist of four additional essays with a preface by Prof. Weissmann.

2. *Ostwald's Klassiker der exakten Wissenschaften.* (Wm. Engelmann, Leipzig).—The volumes of this series last issued include:

No. 25. Unterredungen und mathematische Demonstrationen über zwei neue Wissenszweige, die Mechanik und die Fallgesetze betreffend von Galileo Galilei. Fünfter und Sechster Tag (1838).

No. 26. Über die Constitution der organischen Säuren von Justus Liebig (1838).

No. 27. Untersuchungen über die Kakodylreihe von Robert Bunsen (1837–1843).

No. 28. Über die Asymmetrie bei natürlich vorkommenden organischen Verbindungen von L. Pasteur (1860).

No. 29. Über das Gesetz nach welchem die Einwirkung der Säuren auf den Rohrzucker stattfindet von Ludwig Wilhelmy (1850).

No. 30. Abriss eines Lehrganges der theoretischen Chemie vorgetragen an der K. Universität Genua von S. Cannizzaro (1858).

3. *Minerals: A monthly magazine.* Vol. I, No. 2, New York, Jan. 1892 (published by the Goldthwaites).—The first number of this new magazine has recently appeared and presents in its 30 pages a number of short articles and notes upon a variety of topics interesting to the collector of minerals.

4. *Modern American Methods of Copper Smelting*, by EDWARD DYER PETERS, Jr. Second Edition, revised and enlarged. 398 pp., 8vo. New York, 1891. (The Scientific Publishing Co.).—The first edition of this valuable work appeared some four years since and was at that time noticed in this Journal (XXXV, 88). In the second edition now issued, the work is thoroughly revised, with the addition of considerable new matter which should make it still more widely useful.

OBITUARY.

Dr. JOSEPH LOVERING, for many years Professor of Mathematics and Natural Philosophy at Harvard University, died on the 18th of January at the age of seventy-eight. He was born in Charlestown, Mass., Dec. 25, 1813. In 1836, three years after his graduation at Harvard, he was appointed tutor of mathematics and physics at that institution, and two years later he began the duties of his professorship; this position he held until his death, although some three years since he was relieved from active labor. In addition to his college work, he gave nine courses of twelve lectures each, before the Lowell Institute, and other briefer courses before the Smithsonian Institution, the Peabody Institute of Baltimore and at other points. From 1867–76, he was connected with the U. S. Coast Survey, and had charge of the computations for determining by cable trans-atlantic longitudes. He was elected a member of the National Academy of Sciences in 1873, and in 1879 he received the degree of LL.D. from Harvard. For nearly twenty years he was the permanent secretary of the American Association, and in this latter capacity, edited fifteen volumes of the proceedings of the association. In 1873 he was made its president; his presidential address upon the Mathematical and Physical state of the Physical Sciences, is published in vol. viii, (1874) of this Journal. Several of his physical papers have appeared in this Journal, and many others, a partial record of an active life, are to be found in the publications of the American Academy of Arts and Sciences and elsewhere. He leaves a widow, two sons and two daughters.

WILLIAM P. RUST, who for a number of years was in the employ of the U. S. Geological Survey as a collector, was taken suddenly ill while engaged in his work at the celebrated Trilobite locality, near his home at Trenton Falls, N. Y., and died a few days thereafter (on the 17th day of October,) 1891, aged 65 years. Mr. Rust was connected with the work of Mr. Charles D. Walcott upwards of twenty years, and collected large series of fossils under his direction. He also made large collections of Trenton fossils that are now in the Museum of Comparative Zoology, Cambridge, Mass., the New York State Museum, the Museum of Cornell University and in the National Museum. His skill in working out the trilobites and other fossils from the Trenton and the Chazy-Calciferous limestones in New York and

Vermont has given to the collections made by him a value that places him amongst the contributors to the advancement of American paleontology. C. D. W.

Sir Andrew Crombie Ramsay, Director-General of the Geological Survey of Great Britain from 1871 to the close of 1881, died on the 9th of December, 1891. His various geological investigations gave him high rank among geologists, and brought him many honors. He was elected President of the Geological Society in 1862, and President of the British Association in 1880, and was knighted in 1881, when, on account of the condition of his health, he resigned his connection with the Geological Survey. As a biographical notice in *Nature* by his successor in the Survey writes, "the news of his death will carry regret into the hearts of many men of science all over the world." The notice, in its closing paragraph, portrays, as follows, a side of his character not well known in America.

"There was in Sir Andrew Ramsay such simplicity and frankness that men of the most diverse natures were attracted to him, and as they came to know him more intimately, the gaiety and kindheartedness of his disposition attached them to him in the closest friendship. Fond of literature, and glad to relieve the pressure of his scientific work by excursions into the literary field, he had acquired a range of knowledge and of taste which gave a special interest to his conversation. Now and then he found time to write an article for the *Saturday Review* in which this literary side of his nature would find scope for its exercise. But the daily grind of the official treadmill left him all too little time for such diversions. His death removes from our midst one of the foremost geologists of our day, and from the friends who knew him in his prime, a large-hearted, lovable man, whose memory they will cherish till they too pass away.

Dr. Ferdinand von Rœmer, Professor of Geology and Paleontology in the University of Breslau, and long an able and active laborer in these departments, died at Breslau, on the 14th of December, in his seventy-fourth year. He made an honorable record for himself in American science by his excellent memoirs on the paleontology of Texas and Tennessee: Die Kreidebildungen von Texas und ihre organischen Einschlüsse, 1852, and Die Silurische Fauna des westlichen Tennessee, 1860, each about 100 pages in quarto, with descriptions of a large number of species and admirable figures on many plates.

Dr. Rœmer's Jubilee as Professor was to have been celebrated on the 10th of next May.

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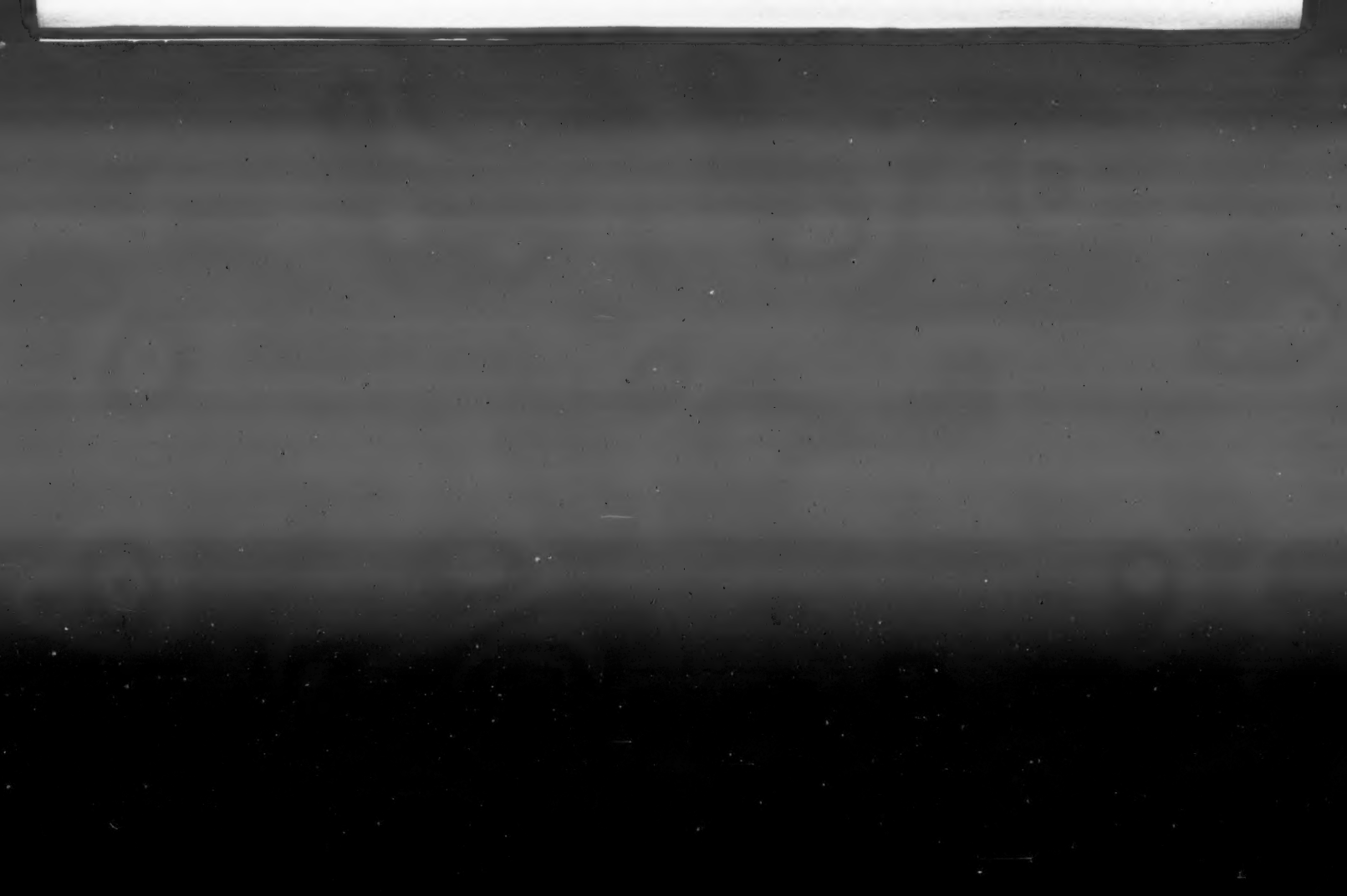

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